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1947 - 1948

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THE Association was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of 900 men. Its membership is divided into six classes, viz.:

A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

A Junior shall be not less than eighteen years nor more than twenty-five years of age, a student or connected with water supply work.

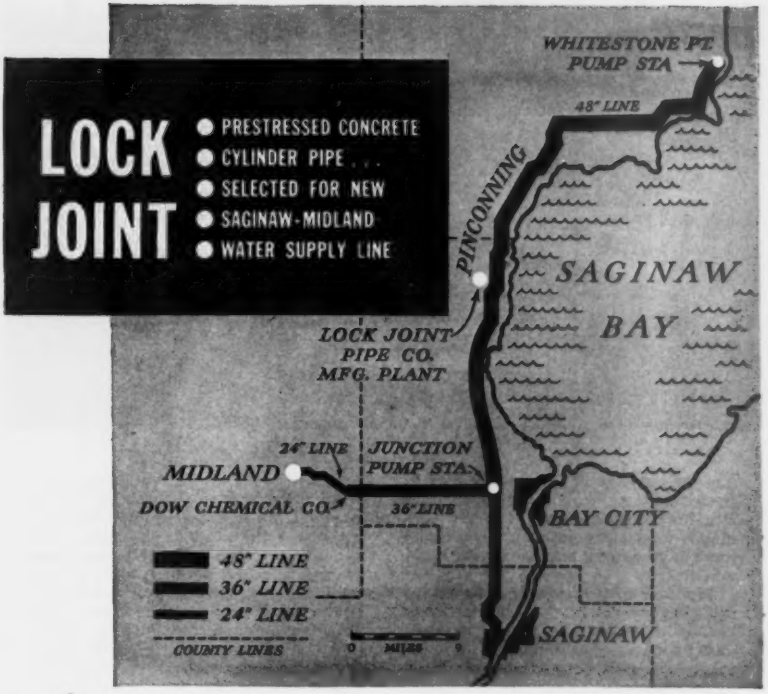
An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

The initiation fees and annual dues are as follows:

	Initiation Fees		*Annual Dues*
Members	$ 3.00	Members	$ 6.00
Juniors	1.00	Juniors	3.00
Associates	10.00	Associates	20.00
Corporate Members	10.00	Corporate Members	10.00

This Association has at least eight regular meetings each year, of which five are held in Boston, one in northern New England, one in southern New England, and one, the annual convention, held in September on such date as the Executive Committee may designate.



ONCE AGAIN, Lock Joint Prestressed Concrete Cylinder Pipe has been selected for a major water works project.

SPECIFICATIONS issued by the Saginaw-Midland Water Supply Commission call for the manufacture and installation of 254,500 feet of 48 inch pipe . . . 143,230 feet of 36 inch pipe . . . 14,900 feet of 24 inch pipe . . . all operating at a pressure of 130 pounds.

WHEN COMPLETED, this 78 mile water supply line will be capable of delivering 23 MGD to the city of Saginaw and 20 MGD to Midland.

BY SELECTING Lock Joint Prestressed Concrete Cylinder Pipe, the Saginaw-Midland Water Supply Commission assures itself of a pipe line of maximum elasticity, permanent high carrying capacity and an estimated life of one hundred years or more.

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Established 1905

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SCOPE OF SERVICES—Lock Joint Pipe Company specializes in the manufacture and installation of Reinforced Concrete Pressure Pipe for Water Supply and Distribution Mains in a wide range of diameters as well as Concrete Pipe of all types for Sanitary Sewers, Storm Drains, Culverts and Subaqueous lines.

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When you buy disc meters, think of tomorrow as well as of today. Buy Pittsburgh Arctic or Tropic type—you'll find they cost less because they measure more.

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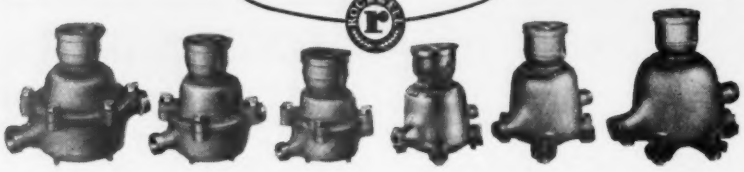
TROPIC
SPLIT CASE TYPE
Ask for Bulletin W-805

PITTSBURGH DISC WATER METERS

ARCTIC
FROST PROTECTED TYPE
Ask for Bulletin W-804



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SOLUTION:

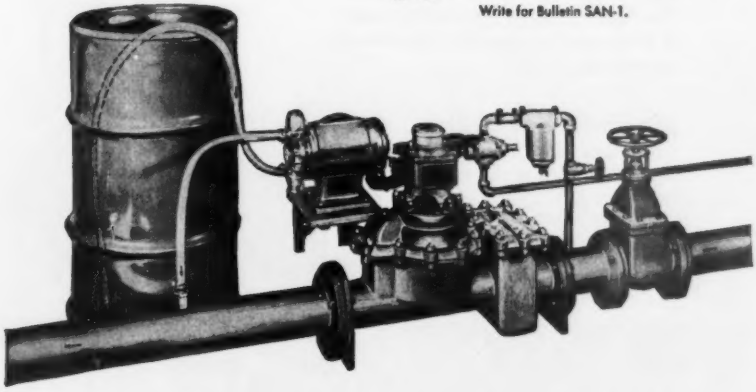
%PROPORTIONEERS% AUTOMATIC AND PROPORTIONAL CHEM-O-FEEDER!

Just install %Proportioneers% Automatic and Proportional Hydraulically operated Chem-O-Feeder and a standard water meter. It is only necessary to know the minimum, average, and maximum flow to be sterilized and the pressures against which the chemical will be injected. All flow is measured by the mechanical water meter and %Proportioneers% equipment starts, varies and stops dosage of chemical in step as the water comes on, fluctuates and tapers off. The %Proportioneers% Low Pressure Chem-O-Feeder shown is treating gravity water supplies against pressures up to 100 p.s.i. Installation is simple and our nearest sales and service representative will assist you in the selection of proper meter and equipment.

RESULT: Fully automatic sterilization of water supply, with chemical fed in strict proportion to flow, without dependence on electricity or other source of power. The only attention required is the occasional refilling of solution tank and checking the chlorine residual to adjust dosage for any variation in the chlorine demand of raw water.

CONCLUSION: Whatever your water treating problem, %Proportioneers% can help you; ask us for recommendations and quotations. Our experience from over 23,000 installations is at your service.

Write for Bulletin SAN-1.

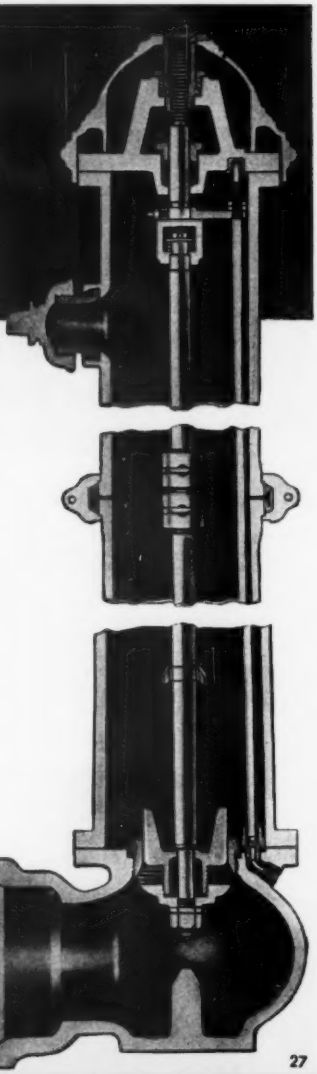


% PROPORTIONEERS, INC. %

63 CODDING ST., PROVIDENCE 1, R. I.

THE

SMITH *Protectop* HYDRANT



Collision damage quickly repaired
Breakage is confined to easily replaceable frangible stem and stand pipe couplings.

Frost can't heave the hydrant
The taper on the stand pipe breaks the grip as the frozen ground rises.

Drainage under pressure can't undermine hydrant
The Smith positive action drain valve is never open unless the main valve is *completely* closed.

Maximum delivery
The stand pipe area is more than twice that of the hydrant valve area.

27

THE A. P. SMITH MFG. CO.

ESTABLISHED 1896

EAST ORANGE, NEW JERSEY

Engineering Facts about
Johns-Manville TRANSITE PRESSURE PIPE
Making Large Service Connections

READY adaptability to standard waterworks practice is an advantage of Transite* Pressure Pipe which is of special importance when making large service connections. Thousands of such connections are in service today, installed in Transite supply and distribution lines with standard equipment and tools under a variety of installation and working conditions.

A 24-inch Transite main being tapped under full working pressure for a 20-inch branch connection.

For tapping the line under pressure, conventional tapping sleeves, tapping valves and drilling machines are generally used. The sleeves are first leaded and caulked in the usual manner. Sleeves to fit all sizes of Transite Pressure Pipe are available from several manufacturers. Tough and strong, the pipe wall is, nevertheless, readily drilled; Transite's unusual machinability assures a clean cut.

In cases where the line can be temporarily removed from service, a commonly used method of providing large connections is to insert into the line a fitting† such as a tee having the required outlet size. To do this, a section of pipe is first removed from the line. The Simplex Coupling permits quick removal and with a minimum of trench excavation. Two stubs of pipe are then cut from this section and inserted into the bells of the fitting to form an assembly of equivalent length to that of the section removed. No problem arises in joining stub ends and fitting, since lead or compound joints are readily made with Transite. Replacement of the assembly in the line is easily and quickly made with the standard Simplex Couplings.

A method sometimes used for making connections when the line is under pressure is the use of service clamps of the type equipped with double straps. These may be used for making service connections larger than those recommended for corporation stops inserted directly into the wall of the pipe or where multiple corporation stops are not used. After the service clamp and corporation stop are attached, the pipe wall is drilled with conventional drilling tools. Service clamps are not used for outlets exceeding one-quarter the diameter of the street main, nor larger than 4".

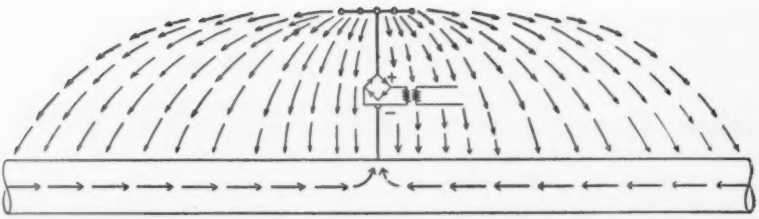
A previous advertisement in this series discussed tapping Transite Pressure Pipe for small service connections. A reprint is available on request. Address Johns-Manville, Box 290, New York 16, N. Y.

†The run of the fitting should have bell ends. Enlarged bells are used for class 150 pipe over 8" diameter.

Conventional methods are used for making large service connections in Transite lines. Here are shown a tapping sleeve and valve being installed on a 12" line under pressure for a 4" outlet.

*Transite is a registered Johns-Manville Trade Mark

JOHNS-MANVILLE JM PRODUCTS



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INCREASE THE LIFE EXPECTANCY OF YOUR PIPELINES

Barrett* Coal-tar Enamels, because of their low moisture absorption under varying conditions of the soils, provide a constant, uniform and long-lasting resistance to electrical leakage.

Mechanically applied by modern methods, these coal-tar enamels assure the proper continuity of the insulation.

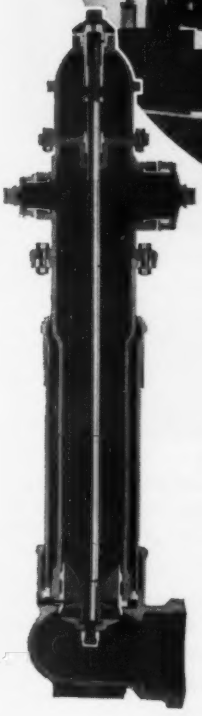
Electrical inspection improves the quality of application and the handling of pipe during construction and, together with a protective pipe coating of stable dielectric strength, makes cathodic protection economical.

This combination permits the use of a minimum number of cathodic protection units, spaced the maximum distance, and a minimum investment in the complementary electrical protection. A dependable procedure when designing corrosion-proof pipelines.

FIELD SERVICE: The Barrett Pipeline Service Department and staff of Field Service men are equipped to provide both technical and on-the-job assistance in the use of Barrett* Enamel.

THE BARRETT DIVISION
ALLIED CHEMICAL & DYE CORPORATION
40 Rector Street, New York 6, N. Y.

*Reg. U. S. Pat. Off.



WORCESTER, MASS.

"One of America's Safest Cities"

The Mathews firemen say

THAT'S A TRUE STATEMENT. For Worcester is protected by Mathews Hydrants—and wherever there's a Mathews there's safety *plus*. Generations of service have proved the dependability of Mathews Hydrants. In these great hydrants there is virtually nothing that *could* go wrong. The stuffing-box plate, cast integral with the nozzle section, keeps water from reaching the threads and rusting them. The revolving nut is protected against rain, dust and dirt, assuring free, quick operation. The heavy stop nut prevents stripping of the stem threads. The main valve is true compression-type. Drainage is complete.

Cities and villages the world over are relying on Mathews Hydrants. Give your community this proved safety *plus*. Send for illustrated booklet.

OTHER MATHEWS FEATURES: Head can be rotated 360° • Replaceable head—nozzle outlets easily changed • Nozzle levels raised or lowered—no excavating • Protection case of Sand-Spun cast iron for extra strength, toughness, elasticity • Removable barrel—containing all working parts

MATHEWS HYDRANTS

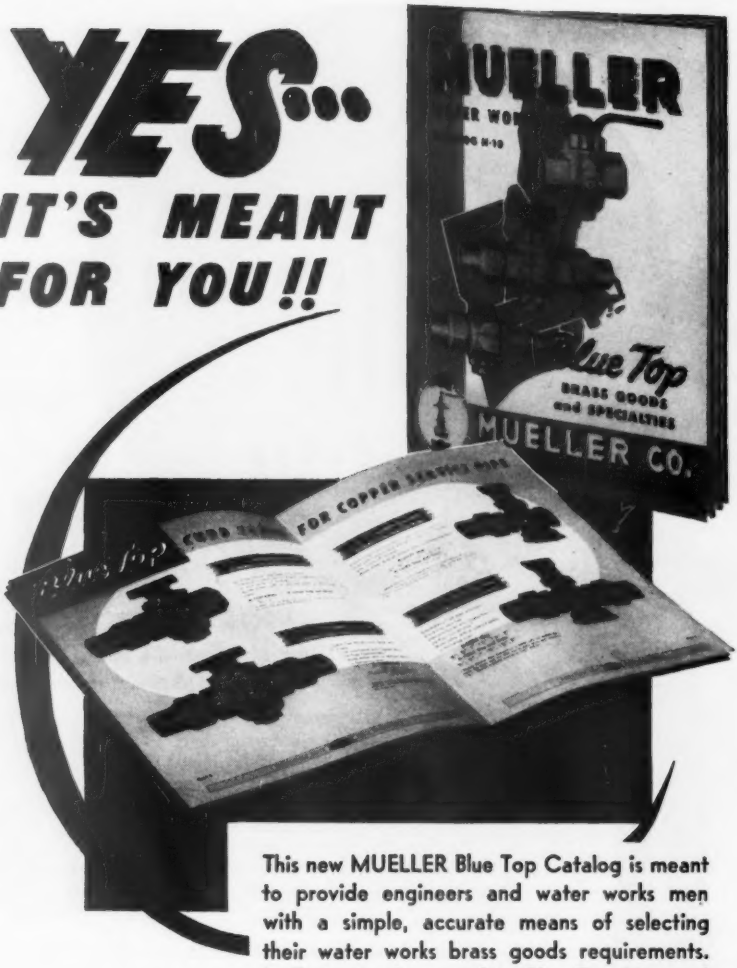
Made by R. D. WOOD COMPANY

Public Ledger Bldg., Independence Square, Philadelphia 5, Pa.

Manufacturers of "Sand-Spun" Pipe (centrifugally cast in sand molds) and R. D. Wood Gate Valves

YES...

IT'S MEANT FOR YOU!!



This new MUELLER Blue Top Catalog is meant to provide engineers and water works men with a simple, accurate means of selecting their water works brass goods requirements. It illustrates the complete Blue Top Line and gives full dimensional data on each item. You'll find it invaluable for constant reference, so if you haven't a copy handy right now, don't delay — write for one today.

DEPENDABLE SINCE 1857 FULLY WARRANTED OUR 91st YEAR

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MAIN OFFICE AND FACTORY DECATUR, ILLINOIS
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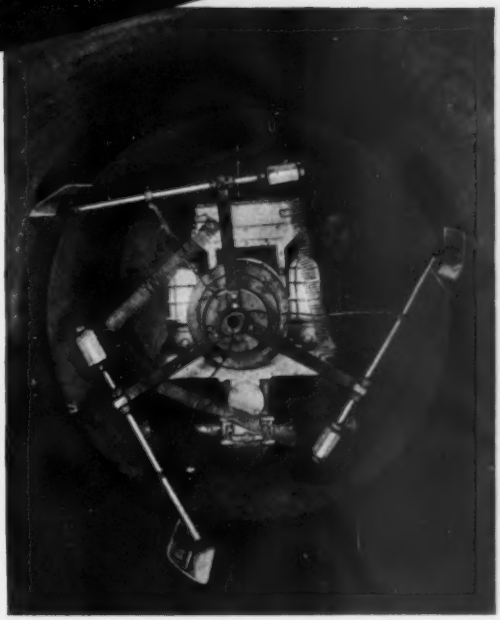
CENTRILINE

CONFORMS STRICTLY WITH A.W.W.A. SPECIFICATIONS

▶▶▶ PIPE LINING FACTS NO. 3



▶▶▶▶ The Standard Specifications for cement-mortar protective coatings issued by the American Water Works Association provide: "Interior of the entire line, including both curves and tangents, shall be by centrifugal machine . . . the machine shall apply the mortar by centrifugal action without the use of compressed air and follow its application by automatic trowelling to a uniform thickness and smooth finished surface."

The strict adherence to these specifications by Centriline insures a continuous, dense, smooth lining—applied without rebound—that means restored carrying capacity perpetually sustained and longer life to mains. If pipelines are losing efficiency it is time to consider Centrilining. Our engineers stand ready to assist you.

▶▶▶▶ WRITE TODAY FOR THE NEW CENTRILINE CATALOG

CENTRILINE CORPORATION

144 CEDAR STREET • NEW YORK 6, N.Y.

CEMENT MORTAR LININGS FOR WATER MAINS

Centrifugally Applied in Strict Conformity with A. W. W. A. Specifications

Put in service, 1921, and examined 1933; awarded business to Badger ever since

The engineer of a large southwestern city's Water Works wrote this: "A Badger Meter, in service since 1921, was removed for inspection. Examination indicated it was in excellent condition, with the exception of a part that was replaced at a cost of ten cents, and the meter returned to service."

Since then this city has bought Badger Meters. You, too, can depend on their durability, precision-construction, and sustained accuracy at lowest cost.

Every waterworks superintendent should have a copy of our new chart: "Table for Determining Service-Pipe and Meter Sizes", No. 676 (no charge).

BADGER METER MFG. CO.
Milwaukee 10, Wis.

BADGER Water METERS

ACCURACY · LOW COST MAINTENANCE · DURABILITY · DEPENDABILITY

BRANCH OFFICES:
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SAVANNAH, GA. • CINCINNATI • CHICAGO • KANSAS CITY, MO.
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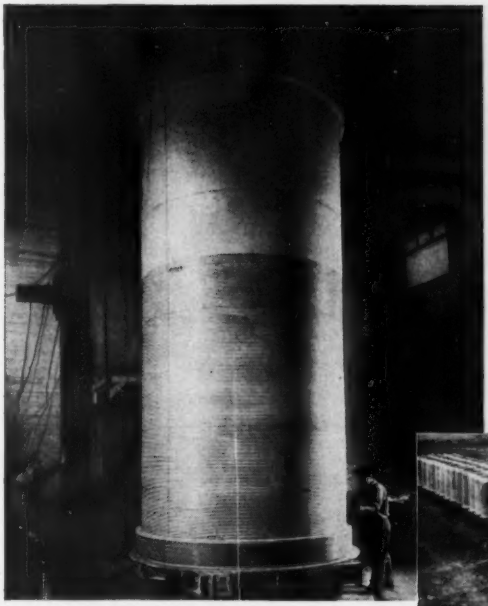
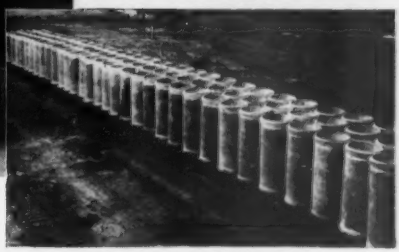
PRESTRESSED CONCRETE PRESSURE PIPE *by* PRELOAD

....Pioneers in Prestressed Concrete Design and Construction



Winding high tensile strength wire on an 18 ft. length of 84 inch diameter Preload Prestressed Concrete Pressure Pipe at Montreal, Canada.

Finished lengths of pipe stored ready for installation in the new Montreal-St. Lawrence water supply intake.



Specify Preload Prestressed Pressure Pipe to attain the following advantages in economy, performance and capital investment value:—

1. **Thinner wall and corresponding lighter weight.**
2. **High internal bursting strength.**
3. **Great external loading strength.**
4. **Substantial economies due to lower first cost; long-term freedom from corrosion and corresponding sustained flow capacity; low maintenance cost; immediate availability of materials.**

Preload is now applying the well known advantages of prestressed concrete construction to pressure pipe of 20 inch diameter and larger, and also is using the Preload-Rocla Internal Expansion Method to make pressurized, prestressed concrete pipe in diameters of 6 inches and larger.

The illustrations show Preload Prestressed Pressure Pipe for the Montreal Municipal Water Supply System's new intake from the St. Lawrence River—a pipeline approximately 10,000 feet in length designed to eliminate the less desirable Ottawa River water.

Each pipe section of 84 inch diameter is 18 feet long and weighs 18 tons. Utilizing the well known Preload Wire Prestressing System the units are built on the site, a procedure which insures no delays, no transportation problems.

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420 LEXINGTON AVE., NEW YORK, N. Y.

Designers and Builders of Prestressed Concrete Storage Tanks and Pressure Pipe
Prestressed Concrete Bridges and Cement Lining of Pipe in Place

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Preload Central Corporation
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PRELOAD

Preload Pacific Corporation
San Francisco—Los Angeles

The Preload Co. of Canada, Ltd.
Montreal—Toronto—Halifax

Consulting Engineers, J. E. Sirrine Company; General Contractors, Diamond Construction Company and Shepherd Construction Company; pipe supplied by Bethlehem Steel Company.

KOPPERS

BITUMASTIC*

PROTECTS THIS 14-MILE PIPELINE INTO SAVANNAH

KOPPERS

THIS 14-MILE PIPELINE will carry 35,000,000 gallons of water daily to the City of Savannah, and to a large paper mill in the area. It passes through swampland where corrosion is the big problem.

To prevent corrosion from these severe conditions, the exterior of the pipe is protected with Koppers Bitumastic 70-B Enamel. For the pipe interior, freedom from corrosion, rust and tuberculation, and continued high flow coefficients are assured by a glass-smooth spun lining of the same impervious coating.

Specify Bitumastic coatings—proven leaders for over 90 years in protecting metal, concrete and masonry. Write for data on your particular problem.

*Reg. Trade Mark, U. S. Pat. Off.

KOPPERS COMPANY, INC. DEPARTMENT 915T PITTSBURGH 19, PENNSYLVANIA

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New England Water Works Association
ORGANIZED 1882

VOL. LXII SEPTEMBER, 1948 NO. 3

This Association, as a body, is not responsible for the statements or opinions of any of its members

GYPSY MOTH CONTROL WITH DDT

BY J. M. CORLISS*

[*Read January 15, 1948.*]

APPROXIMATELY 250,000 acres of woodlands have been treated for the control of gypsy moth with DDT by the U. S. Bureau of Entomology and Plant Quarantine together with cöoperating agencies, especially the Bureau of Plant Industry of the Pennsylvania Department of Agriculture and the New York Conservation Department. We started using DDT for gypsy moth control in the summer of 1944, when we sprayed approximately 5,000 acres. More than 82,000 acres of forests infested with this insect were treated with DDT in 1946 and more than 163,000 acres, or 255 sq mi, were treated in 1947.

The gypsy moth seems to have survived in only three small locations in the area treated by airplanes in 1946. We think this was due to the fact that the treatment was applied too late in the season. There may have been some early pupation of the gypsy moth in these places and DDT is not effective against the pupae. A small infestation was found also in 1947 in one place that had been treated in 1947. This infestation was found early, the area was re-treated, and the insect has not been found there since. Spraying was discontinued in 1947, well in advance of pupation.

All treated areas have not been thoroughly examined. However, many of the pockets known to have been heavily infested previously have been critically examined up to August, 1947. No infestations have been found in any of the areas that were treated. Further examination by use of sex-attractant traps may lead us to infestations, if they are present, and the areas will be examined later by manual surveys.

We use glass plates in the forests to check the actual deposit of

*In Charge, Division of Gypsy and Brown-tail Moths Control, Bureau of Entomology and Plant Quarantine, Agricultural Research Administration, U. S. Department of Agriculture, 20 Sanderson St., Greenfield, Mass.

DDT during spraying. Approximately 5,200 plates were used in Pennsylvania, all but 125 of which were found to have received a good deposit of DDT. The areas from which plates with unsatisfactory deposits were taken were re-sprayed.

N3N-3 biplanes have been most frequently used in the work. Pilots have treated more than 1,000 acres a day on several occasions with one such plane. We have just acquired two Douglas DC-3 airplanes, one of which will be equipped for spraying next summer. This type of plane carries 1,000 gal of spray material and will treat 1,000 acres of woodland in 10 min or less of flying time. High-speed blowers on the ground can treat 75 to 100 acres of woodland along roadsides daily.

All our work has been done in close coöperation with other agencies. Early experiments were carried on by the Research Divisions of our Bureau. They had to determine the proper formulations of DDT to be used, the most suitable time of application, and the best type of equipment for the purpose. It was not at first known how effective this insecticide would be against the gypsy moth and what effect the material might have on other insect and animal life, including birds, bees and fish. It was necessary to determine whether it would be harmful to forest foliage or indirectly to human beings. In the early research work, we assisted responsible Federal, State and local agencies.

A test was made in August, 1944, to determine if, as a result of applications made to forest areas, enough DDT would get into a water reservoir to be hazardous to humans drinking the water. A watershed consisting of approximately 40 acres, surrounding a pond of about 4 acres, which contained approximately 1½ mil gal of water, was sprayed by airplane. Five pounds of DDT in 5 gal of oil solution were used per acre. The pilot did not fly directly over the pond but some of the insecticide drifted onto it. Many kinds of insects were killed both on land and in the water. A few frogs and small fish were killed. However, the area was quickly repopulated. Before and following the spraying, samples were taken of the surface mud and of the water. Careful analysis showed there was not enough DDT in the reservoir to be harmful to human beings. Analysis showed that only 0.01 ppm of DDT had leached into the reservoir.

Since this is equivalent to one part in 100,000,000, a human would have to consume about 25,000 gal of water to ingest one gram into his system. The Food and Drug Administration of the Federal Security Agency rendered an opinion that watersheds, treated at the rate of 5 lb of DDT in 5 gal of oil solution per acre, would not create a health hazard. Today we are using only ½ or 1 lb of DDT in 1 gal of oil per acre for control of the gypsy moth.

Throughout four years of spraying with light applications of DDT, careful observations have been made, in coöperation with the Fish and Wildlife Service and other agencies, to determine the effects of DDT on wildlife. No injury has been noted. These observations have been carried on in treated areas in New England, New York and Pennsylvania. Observations similar to those made by ornithologists in Pennsylvania have been carried on in New York, Massachusetts and Vermont. No injury has been reported to birds even during their nesting period.

A test area one mile square was treated for insects in 1945. A careful census was made of insect and bird life prior to, during, and following the spraying. At the beginning of this experiment 5 lb of DDT in 5 gal of oil solution were applied per acre. This resulted in minor mortality to birds. The dosage was then reduced to 1 lb of DDT per acre. Since that time there has been no mortality or disturbance of birds noted in the forests which have been treated with a 12 or 6% solution, applied at the rate of 1 lb of DDT to the acre. Many insects besides the gypsy moth, including many beneficial ones, were killed within the area, even at the 1-lb dosage, but the area was repopulated by many species, though not by the gypsy moth, within a few weeks, either by infiltration or reproduction from survivors. This area has been examined on numerous occasions since, and the general insect and bird life appears to be normal.

A beehive was placed in this block before spraying with DDT. This colony was examined later and found to be in as good condition as a check hive in an unsprayed location. Since then, both hives have been kept in the yard of our Moosic property in Pennsylvania. All of the area surrounding them has been sprayed with DDT at least once and much of it several times in connection with demonstrations. These hives have continued to be healthy and normal.

A fish census was made of a mile-long brook running through a forest area, stocked with live-fish traps, during the early experimental work. This stream was treated at the rate of 1 lb of DDT in 1 gal of oil per acre.* The pilot was instructed to fly some 50 to 75 ft from both sides of the stream, guided by markers. As the swath delivered by the plane was about 100 ft in width, some DDT drifted into the stream. An examination of the stream following the spraying showed no mortality of fish. A three-mile stream was treated in another area, the same material and dosage being used. A census was made of the fish in this stream and several weirs were used; also several live-fish traps were installed. The pilot flew directly up and down the stream and re-flew parts too crooked to cover during the initial flight. A thorough examination was made following the spraying and a few dead fish were found in the lower end of the stream. Only one per cent of the trout were killed.

No burning of foliage of forest trees has been reported in the extensive woodlands treated by airplanes with DDT at recommended rates of application. The material is very finely atomized and excellent distribution has been obtained. Burning of foliage, especially of maple, has resulted in some cases following the application of DDT in oil solutions, when applied by the axial-flow air-type ground blowers. This has usually occurred on trees which received the direct blast from the blower. Burning has resulted in some cases where knapsack sprayers have been used. In most instances, it is believed that this was due to over-spraying and the burning was caused by excessive oil. Men who have been trained in using hydraulic equipment have a tendency to over-spray when using concentrated insecticides. Only a very small amount of DDT is necessary to obtain control of the gypsy moth.

Hydraulic equipment has been used very satisfactorily for applying DDT sprays in many locations. Many towns and cities, property owners, and commercial concerns have one or more hydraulic sprayers and there is no reason for junking such equipment. We are not using hydraulic equipment at this time because our program calls for the treatment of very extensive areas. The newer equipment requires less material and less man-power and is much more economical. There has been so much said during the last few seasons about airplanes

and blowers for distributing insecticides that it should be pointed out that there is still a place in pest-control work for hydraulic spray equipment This will probably continue for a long time.

This is the present story of the use of DDT for gypsy moth control and eradication work as carried on by the Bureau of Entomology and Plant Quarantine and coöperating agencies. Those of us most closely concerned with this work are extremely enthusiastic about this new insecticide, because of the amazing results which have been economically obtained. We feel that we can now exterminate the isolated infestation in Pennsylvania quickly and that we can gradually move the infestation in New York State toward the east.

Discussion

Donald C. Calderwood (Nashua, N. H.). How much does that cost per acre?

J. M. Corliss. That is one thing I avoided and I am glad you asked the question. The cost of the hydraulic equipment was never lower than $15 an acre in 35 years of operation by the Division of Gypsy and Brown-tail Moths Control. The cost of spraying 106,000 acres by airplane last spring, comprising districts in New York, Pennsylvania and the New England States—they furnishing the material and we furnishing the equipment and doing the flying—was $1.30 an acre by airplane, and that figure was the cost plus 10%.

THE ALGAL ENVIRONMENT IN RELATION TO FISH

BY ALLAN S. KENNEDY*

[*Read January 15, 1948.*]

ALGAE and those plants and small animals associated with them in an aquatic environment are dependent upon many external factors for their growth and reproduction, of which food, temperature and sunlight have possibly the greatest immediate effect.

The food situation is extremely complex, as each species has certain requirements which are different from those of a near relative. In experimental work, it has been found that very great differences exist among the various species of algae.

From this complex situation it is possible to state that some form of nitrogen is a necessity and that, with other factors being normal, the productivity of reservoirs varies directly with the total amount of available nitrogen. This is found free, as ammonia, nitrites and nitrates. All animals and plants, with the exception of a few bacteria, require some form of nitrogen for life and the production of protein.

In a pond, there is a definite nitrogen cycle—that is, nitrogen and its compounds are being given off into the water, by the decomposition of organic debris on the bottom. This is utilized by bacteria, plants and the smaller forms of animal life, and upon their death this material again settles to the bottom to start the cycle over again.

In this situation, the fish, by eating plant and animal life, converts the material to his own use. Upon his death, it returns to the bottom deposits and so is ready to begin the next cycle. Additional nitrogen-bearing material enters from the watershed drainage and this increases the total available amount.

The productivity of a body of water, as far as this nitrogen cycle is concerned, is dependent upon the type of basin and the amount entering and leaving the pond. In practice we find that, by the addition of fertilizers, we are able to step up the production of aquatic

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plants and animals to very high levels. In October, I had an occasion to observe an algal bloom on a lake in New Brunswick which definitely was due to fertilization. This lake was of a type which never produced a real bloom, as the amount of food present was too scanty.

The relationship between algae, fish and sunlight is very interesting. In a reservoir or lake which has a heavy algal growth, a reduction in the amount of sunlight will reduce the photosynthetic activity of the algae, thereby causing them to use oxygen stored in the water. If this condition exists for any length of time, the water will lose most of its oxygen and the fish will die of oxygen starvation.

On the other hand, the normal amount of sunshine on a very thick growth of algae can cause the death of fish. In this case, the algae are so thick that they do not permit the passage of light to the algae which are somewhat below the surface. These use up more oxygen than is produced by those on the surface and oxygen depletion takes place. It can be said, therefore, that a very delicate balance exists between the amount of algae, the amount of sunlight, and the total oxygen requirements of the fish. A rise in water temperature might be the factor which starts an excessive growth of algae and thereby sets off the chain of events which finally causes oxygen starvation.

Two of the most intensely studied bodies of water in this country are Lakes Mendota and Monona at Madison, Wis. These lakes have been under scientific investigation for over 30 years and much of our basic knowledge of the complexities of aquatic life have been recorded there. It has been estimated that Lake Mendota produces each year approximately two tons of algae per acre. In addition to the algae, it produces a few hundred pounds of minute animal forms which are distributed through the water. This does not take into account the many pounds of bottom organisms which should be included, if a total production figure were to be determined. This appears to be an enormous number of pounds per acre and the question therefore arises as to how many pounds of fish this body of water supports. The dominant species in this lake is the yellow perch and it has been estimated that the total weight per acre is 20 lb. Even if we decide to multiply this number by two, we still get what the average person would call a low production of fish for such a high poundage of plants

and small animals. This bears a close resemblance to that proverbial "drop in the bucket."

In some of our fish cultural ponds, where we raise pondfish—or I should say where pondfish raise themselves upon natural food—and we take advantage of them, I attempted to calculate the weight of fish produced per acre and was very much disappointed to find that it was not much better than Lake Mendota.

In this part of the country, where the summer is short and the winter long, we cannot expect the production of fish to equal that of some of our southern states, where a much greater production has been reported.

Actually the time of year which most limits the number of pounds of fish per acre is the winter, since in most bodies of water there is oxygen depletion, a small amount of food, and competition which is very keen. In the investigations of fish populations it was found that June and July naturally had the greatest number of fish per acre, but this number decreased rapidly in August and September, so that by December or January the number had returned to a very low level.

It is a well known fact that, when a new pond or reservoir is flowed, for one to two years, depending upon the area flowed, the fish production increases enormously. Within a few years, the organic material which was on the bottom at the time of flowing has given off all of the useful ingredients for the production of plants and animals, and the population of fish declines. This decline continues until the total weight of fish is such that it can be maintained by the residual food plus that brought in by the incoming waters. Naturally some food is lost by way of the various outlets and the escape of gases into the atmosphere. Any taking of fish by angling or netting reduces the amount of potential food material.

No doubt many of you have heard stories of the large number of fish in the Quabbin Reservoir. There is no doubt that this reservoir contains a greater poundage of fish per acre at the present time than it will a few years hence. As far as numbers are concerned, they will drop faster than will the poundage, because the total pounds per acre will eventually be made up of a high proportion of large fish with a much smaller group of small ones.

Fish do utilize algae as food in varying degrees but the only

group of fish which I know of that are truly vegetarians—living and growing on a diet of algae alone—comprises certain marine species. In the Hawaiian and Philippine Islands, the natives raise some of these species for food.

That species which I have observed most closely is the Milk Fish, otherwise known to the Filipinos as "Bangos" (Chanos Chanos). These fish spawn in salt water along the northern coast of Luzon, where the young are caught in nets and transported to ponds near Manila. The ponds are prepared prior to the arrival of the fish, by cultivating in them a specific species of blue-green algae. After the fish have been in these ponds for a number of weeks, it is necessary to change their diet or the production suffers. They are then transferred to a second series of ponds, in which a species of filamentous algae has been growing. This species, like the first, satisfies the fish only until they reach a little larger size, when it is again necessary to transfer them to a third pond, containing a species of wide, flat, green algae. Whether or not it would be necessary to produce a different species of algae, in order to carry this fish longer, I do not know, for it is from this third pond that the fish is shipped to market.

This tends to show that even a vegetarian species of fish will select the type of food it wishes and may be very particular about it. In experiments, it has been found that various species in this country are very choosy, if they take algae at all. All of the species of American Game Fishes tend to become anything but vegetarians, even from early life.

Small fish do eat a certain amount of algae but the total eaten is much less than the total volume of other forms of life found in the water. Algae, therefore, appear to be a second choice, the first being those organisms which are capable of some movement, as many fish will refuse to eat anything not able to move. In the culture of fish it has been found that, if both living and dead of certain aquatic organisms, such as daphnia, are introduced, the fish immediately eat the living but may pass up the dead ones and allow them to settle to the bottom.

As the fish grows, his diet changes and he becomes more cannibalistic. After he reaches three to four inches, there are very few which can be trusted to take their little brother out for a swim and bring him back as a free-swimming fish.

Some of the species which do not grow to a large adult size can be found feeding around groups of algae, but, although some algae can be found in the stomach contents, it may be that they were taken because of the fact that some tasty morsel of animal life was attached.

The situation in respect to the species of algae actually eaten was stated by one investigator as resembling the growth on an abandoned pasture, in which cattle were allowed to feed. Some species of grass would be readily eaten, whereas the brambles, young trees, etc., would not be touched. Another has given the opinion that fish enjoy eating algae about as much as humans like a diet of grass. The use of small forms of aquatic life as food continues throughout the fish's life, but he would rather have one good stomach-filling morsel than have to strain gallons of aquatic soup for a few strands of algae.

Reservoirs can be roughly placed in three classes in relation to the amount of algal production. The first class is the envy of all water-supply superintendents, being one in which no algal bloom occurs. This type is usually found to be a lake which is deep, with a very limited shallow area and a very limited watershed, and deficient in the amount of organic nitrogen present for plant and animal life. It is needless to say that the production of fish is very poor. In such lakes, if no overturn occurs, the majority of organic material settles to the bottom and is lost. The second class is an intermediate one, in which an algal bloom seldom occurs but may occur at infrequent intervals. The third class is the one which causes grey hair, by producing an algal bloom at least once but more often a number of times each year. This class of reservoir is usually one with a large watershed, a large amount of shallow water, and a rich supply of organic material.

Other factors being equal, the population of fish in any body of water will balance itself with the food supply. The stocking of additional pounds of fish or other species only serves to increase competition and, within not too long a period, the excess must be reduced by death, disease or starvation.

The netting of the large fish from a reservoir has one beneficial effect, in that it reduces the number of fish eaters and allows a group of small fish to take their place. These small fish dispose of some of the aquatic organisms which might add colors, odors or tastes to the

water. This is not a cure-all, because fish grow and increase in weight, and, as the water can support only a certain amount, the original balance is restored within a short time.

In this connection the Division of Fisheries and Game has been netting fish from various water supplies and some lakes for about 20 years. From one private pond they have taken 30,000 to 100,000 large fish each year and, in spite of this reduction of large fish, the young are not able to keep the water clear of excessive growths of plankton. There is one serious point to this work—namely, that if for any reason this salvage of fish does not take place for a few years, there may be an enormous loss of fish from oxygen starvation, disease or other causes. This would be nature's way of quickly establishing a balance. Such a loss did occur in a lake in which the salvage work had been discontinued some years ago.

In the work at our pondfish cultural units, where we draw down the ponds each year, count the fish produced, and return a definite number of brood stock for the following year's production, we still cannot state definitely that so many adult fish will produce a definite number of small fish the next fall. This is on a system which has been used for this type of work exclusively for over 20 years and almost every combination has been tried, but each year's results vary, even if the numbers are the same.

From these two cases, I believe that you can draw one conclusion and that is that man can never balance a large body of water so that he can definitely state that such and such will happen, because nature is forever changing and blueprints for past or future changes are never issued.

We agree that, if the proper species of fish could be found that would eat all species of algae, and only algae, all would be well, but in this respect you are dealing with variations to the *nth* power and it is impossible for the human brain or any machine to take these thousands of variables and come up with a set of printed directions which will work.

RESULTS OF UNIVERSAL METERING AT THE NAUGATUCK WATER COMPANY, NAUGATUCK, CONNECTICUT

BY WILLIAM H. MOODY*

[*Read February 19, 1948.*]

THE facts and reasoning of the officials of the Naugatuck Water Co. in their decision to install universal metering were published in the May, 1945, issue of *Water Works and Sewerage*. In order that you may readily see the picture, a brief resumé of the above article is given here:

Naugatuck is situated in the southwest section of Connecticut. It is an industrial town with about 17,000 inhabitants.

The Naugatuck Water Co.—a privately owned company—has continuously furnished water to Naugatuck and a section of Waterbury and Beacon Falls, adjoining towns, for the past 59 years. There is a high- and a low-pressure distribution system, each supplied from its own storage reservoir by gravity. The water is soft and the only treatment is chlorination. The total storage amounts to 700 mil gal and the distribution system consists of 59 miles of main.

Consumption had reached the theoretical production of the storage facilities. The solutions were: first, increasing the water storage and constructing a new supply main at a cost of $300,000 and at a yearly expense of $30,000; or, secondly, metering 3,000 domestic and commercial services, which were on a flat or fixture rate, at a cost of $30,000 with a yearly expense of $6,000. Industrial consumption was already being metered. As past experience had shown that such a change was always accompanied by a reduction in the amount of water required to supply the demand of the system, it was decided to install meters. This was done in 1942. The meters selected were 5/8 × 3/4 Trident frost-proof-bottom meters, with a straight-reading dial registering in gallons.

The object of metering was to save wasted water and the only

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increase in income asked for by the company was $2.00 per year per meter, which was the estimated extra cost for metering. After a year's trial a final rate was established, with the income the same as received from the fixture or flat rate before metering, plus the increase due to new consumers, plus $2.00 per meter. The meter rate schedule and the rates for fire protection are shown below.

Meter Rate Schedule

Meter size (in.)	Quarterly minimum charge	When quarterly use of water is less than
5/8	$ 2.70	6,900 gal
3/4	6.00	17,900 "
1	9.00	28,700 "
1 1/4	15.00	54,600 "
1 1/2	20.00	79,600 "
2	30.00	139,200 "
3	50.00	339,200 "
4	75.00	589,200 "
6	125.00	1,089,200 "
8	225.00	2,089,200 "
10	350.00	3,339,200 "

First	6,900 gal or less per quarter	—	$2.70
Next	17,100 ", per 100 gallons	—	.03
Next	21,000 ", per 100 gallons	—	.025
Next	75,000 ", per 100 gallons	—	.02
Next	32,880,000 ", per 100 gallons	—	.01
All over	33,000,000 gal, per 100 gallons	—	.006

Rates for Fire Protection

Sprinklers are charged for as follows:

$.10	per	head	per	year	for the first 500 heads;
.07½	"	"	"	"	for the second 500 heads;
.05	"	"	"	"	for all over 1,000 heads.

Private fire hydrants at a yearly rental of $25.00 each.

The present agreement calls for a yearly rental for each public hydrant of $40.00 per year.

The town was divided into three equal-size districts and each district divided into nine routes of 100 customers. Each customer was given a route and individual number which is shown on a visible index. Accounts are posted on a Kardex System. (End of resumé of article published in the May, 1945, issue of *Water Works and Sewerage*.)

The change to payment for water by meter schedule from the flat or fixture rate appeared difficult when it was started and proved to be more so later. Local politicians and officials of a union opposed the installation of meters and it was the task of the officers of the

water company to prove their case, which was done through the medium of public hearings, pamphlets and the press. The opposition was not always fair and untruths had to be counteracted. Eventually this proved a benefit, as it was necessary to put forth more effort than would have been made without opposition and a thorough selling job had to be done.

When meter bills were high, it was necessary to visit the premises, inspect the plumbing and, in many cases, make a record of the consumption for 24 hr by means of a Brainard Meter Master. More than one-fifth of the homes in Naugatuck were visited and this gave an opportunity to state the facts of the need for metering directly to the people who had the most reasons for opposing the change. The consumers—even those who did not take kindly to the change in payment for water from the fixture rate to the basis of measurement—now appear to be satisfied that universal metering is the fair method of paying for water, just as it is for electricity, bread or any other commodity.

Up to the time that meters were installed, the officials of our company had made no special effort to acquaint the public with the facts concerning the operations of the company and had taken the attitude of "letting sleeping dogs lie". However, discussion of metering brought out the fact that some customers had many erroneous ideas concerning the business of the company and this opportunity was used to correct these false impressions. Without question, these frank discussions have done a great deal to improve public relations.

The meter rate has proved to be equitable and the only revision made since it was established was an increase in 1947 to industrial consumers using more than 33,000,000 gal per quarter, from 6/10 of a cent to 8/10 of a cent per 100 gal. This substitution was made because of the basic cost of water—the summation of all operating costs, depreciation and taxes had increased in four years from $.006 to $.008 per 100 gal. A minimum of $3.00 per quarter in the meter rate schedule was contemplated before meter rates were established. However, the Public Utilities Commission insisted on a minimum of $2.70 per quarter, but $1.00 per month for the benefit of water service is certainly not exorbitant. About 10% of the domestic consumers pay the minimum amount. The cost per family for water for the year

1947 was $14.21 and the domestic consumption per person was 33 gal per day.

A properly conducted water supply should know all the facts about its business. One of the most important is the *quantity* of water consumed and *where* it is used. The only answer to this problem is universal metering. By tabulating the consumption and income in each category, the number of gallons sold and the rate of income per unit can be figured. The difference between the total consumed and the consumption billed is the unaccounted-for water. With a gravity system, it is important to keep this to a minimum and, with a pumped or filtered system, it is even more necessary on account of the additional cost of processing.

Before metering the supply at Naugatuck, it was thought that there was considerable water wasted but the quantity was unknown. After one year with the supply metered, it was found that the unaccounted-for water amounted to 25%. There were no underground piping leaks visible and it was not known where the loss was taking place. A pitometer survey was made, which found some underground leaks and 245,000 gal of water per day being used without being metered.

When meters were installed in factories, no fire lines were metered, as they were supposed to be used for fire protection only. During the years, they were tapped for industrial use. The pitometer survey showed that this condition existed in two of the largest factories in the town and all the *fire* and *production lines* at these plants have since been metered at the connection with the supply main with 4- to 10-in. Trident Protectus or compound meters. As there is a fixed service charge for each sprinkler and hydrant used for private fire protection, an estimate made by the owner of the amount of water used for fire fighting and testing is deducted by the water company from the total amount of water billed. Both of these large plants are dangerous fire hazards and up to 500,000 gal per month have been used for fire prevention. In 1947, the unaccounted-for water amounted to 14%, with no allowance for water for legitimate uses such as fire fighting, flushing, etc., which is estimated to be about 6%. This is not ideal, but the reduction in unaccounted-for water due to the installation of meters and the pitometer survey has made available an

additional 1 m g d, which, if sold at the lowest price in the meter schedule, would be worth $29,200 per year.

If the consumption of water had increased in a normal manner, the production facilities at Naugatuck would have been ample to supply the demand for several years. However, the industrial demand has increased to an unprecedented degree and it is necessary to add to the production source at this time. There is no doubt that the installation of meters was the logical first step, as it has made available 1 mgd with an investment of $35,000. To add the same amount to the production by means of increased storage would cost many times that amount. Installation of universal metering by the Naugatuck Water Co. has resulted in a moderate increase in the cost of water, instead of a large increase, to the consumers. The water company has benefited, due to increased knowledge of the actual use of all the water that is distributed, and has been able to salvage wasted and unmetered water in the amount of 1 mgd, which prevented a water shortage. The company is also in a position to increase further the efficiency of the distribution plant and continue to furnish an ample, safe and palatable supply of water to the consumer at the least possible cost.

Discussion

Harold W. Griswold (Hartford, Conn.). On the large industrial plants, do you lump the consumption of the various meters on the services?

William H. Moody. Yes, we do.

Donald C. Calderwood (Nashua, N. H.). In other words, you totalize all of the services in one plant?

Mr. Moody. That is right.

Mr. Calderwood. You give them the benefit of the lower rate?

Mr. Moody. Yes. We have about two customers that go over 33,000,000 gal of water. One of the things we are up against is leaks —of course everybody is. We had a little pamphlet printed and I brought a few of them along and will pass them out. If anybody would like one, he can have it. Of course, the worst thing we are up against is leaky toilets—everybody is—and lots of people would not be convinced, until we put a meter master on and showed them where the leaks were. Most of them continued all night long.

THE UTILIZATION OF ELECTRICAL AND RADIOACTIVITY METHODS OF WELL LOGGING FOR GROUND-WATER SUPPLY DEVELOPMENT

BY JOHN J. BAFFA*

[*Read February 19, 1948.*]

THERE have been developed in recent years various geophysical methods for surveying the lithology of the wall rocks in bore holes. These methods are at present in an advanced stage of commercial application in oil-well surveying practice and also have found application in the field of ground-water supply development in western and midwestern states.

It has been the writer's privilege to experience the application of these methods to determine the depth, limits and relative porosity of water-bearing strata in water-well bore holes. The following brief description of electrical and radioactivity well logging is presented with the thought that it will be of interest to water-works engineers in the New England States, who are perhaps not familiar with oil-well drilling practices. In addition, these methods are not commonly described in water-works literature.

RADIOACTIVITY WELL LOGGING

Radioactivity well logging is a comparatively recent development, having been made commercially available in 1940. It is the first successfully developed method for indicating the position of sandstones, shales and limestones through holes already cased. Radioactivity logs may also be obtained in open, uncased drill-holes. Two types of radioactivity logging are available and are known as the "gamma-ray log" and the "neutron log". The gamma-ray curve is utilized to log the lithology of the wall-rock formations and combination gamma-ray and neutron logs will indicate the position and relative porosity of the various strata in the drill-hole. The neutron log has not to the writer's knowledge been used in connection with wells for water supply, so that this discussion is confined to the gamma-ray curve.

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The Gamma-Ray Curve

Radioactive materials are present in all rocks and these materials are present in varying concentrations. Shales contain more radioactive substance than do limestones or sandstones. The radioactive materials disintegrate and emit rays, of which the gamma ray is the most penetrating. The measurement of the intensity of emission of the gamma rays—which intensity is proportional to the amount of radioactive material present—provides a means of identification of the various strata in the well hole. In Table 1 are shown the average radioactivities for various sedimentary rocks.

In making a radioactivity survey of a water well, a knowledge of local lithology is necessary for correlation with the gamma-ray curve. This knowledge is obtained from drillers' samples in the hole itself and from knowledge of existing boring data in the general area.

The equipment for obtaining a gamma-ray curve for a well consists essentially of a subsurface instrument, hoist, amplifier and instrument truck.

Figure 1 is a photograph of a radioactivity well-logging truck and Figure 2 shows the interior of the truck, with amplifying and control panels at the left and the automatic pen recorder, which draws the radioactivity log, at the right.

FIG. 1.—RADIOACTIVITY WELL-LOGGING INSTRUMENT TRUCK.
(Courtesy of Lane-Wells Co.)

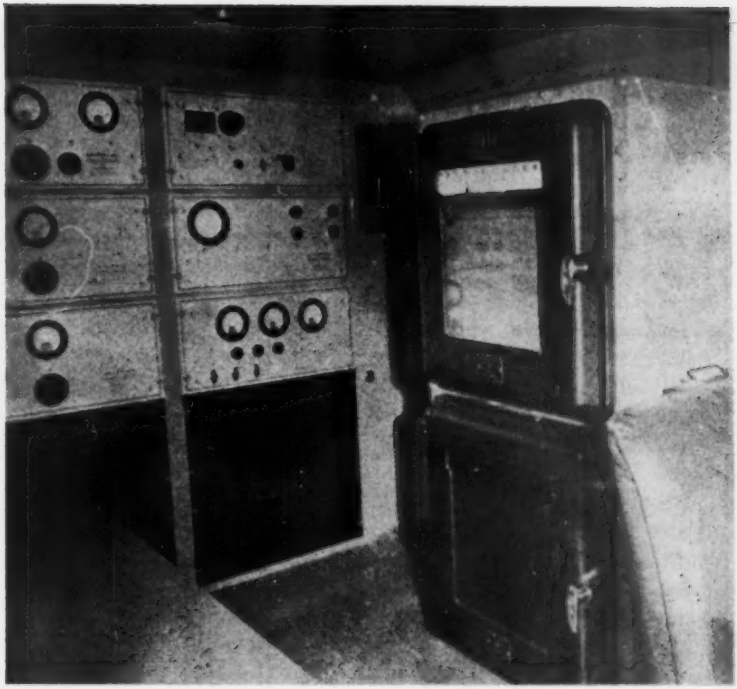

FIG. 2.—INTERIOR OF RADIOACTIVITY WELL-LOGGING INSTRUMENT TRUCK. AUTOMATIC PEN RECORDER, WHICH DRAWS THE RADIOACTIVITY LOG, AT RIGHT; AMPLIFYING AND CONTROL PANELS AT LEFT.
(Courtesy of Lane-Wells Co.)

TABLE 1.—RELATIVE RADIOACTIVITY OF SEDIMENTARY ROCKS

	Total gamma-ray activity*
Black Shales	$25.0—60.0 \times 10^{-12}$
Gray Shales	$15.0—25.0 \times 10^{-12}$
Sandy and Limy Shales Shaly Sandstones and Limestones	$5.0—15.0 \times 10^{-12}$
Sandstones, Limestones, Dolomite	$0.5—5.0 \times 10^{-12}$
Salt, Anhydrite, Gypsum, Coal	Less than 2.0×10^{-12}
Volcanic Ash	$15.0—25.0 \times 10^{-12}$
Potash Rock	$50.0—70.0 \times 10^{-12}$

*Expressed in grams of radium equivalent per gram of rocks.

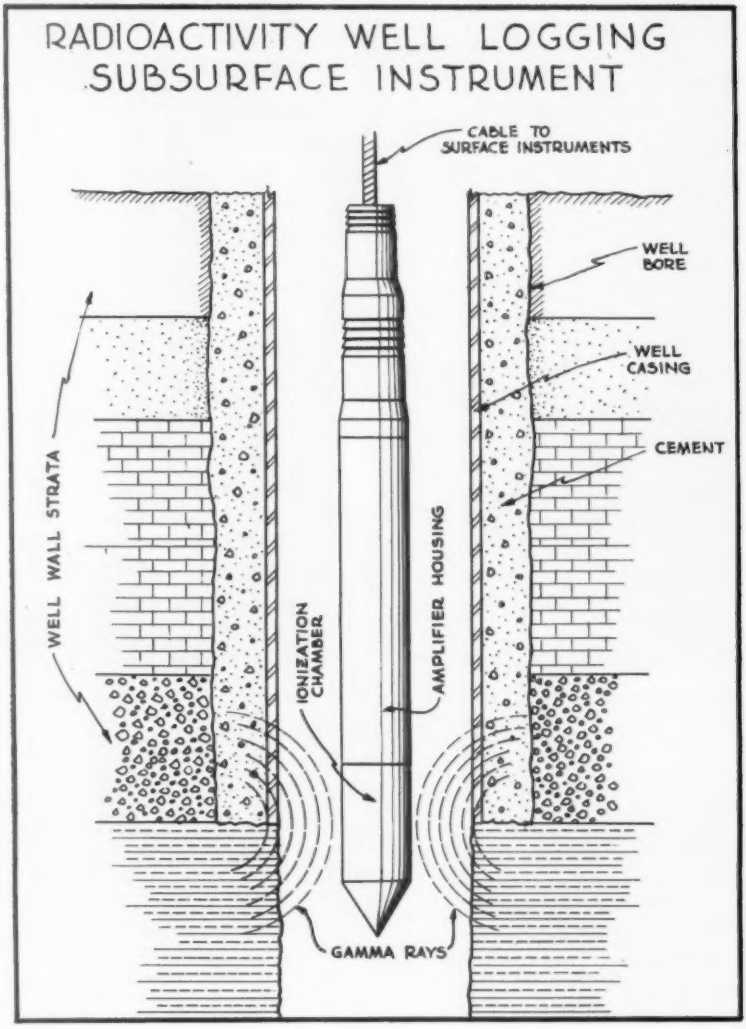
RADIOACTIVITY WELL LOGGING
SUBSURFACE INSTRUMENT
CABLE TO SURFACE INSTRUMENTS
WELL BORE
WELL CASING
CEMENT
WELL WALL STRATA
IONIZATION CHAMBER
AMPLIFIER HOUSING
GAMMA RAYS

FIGURE 3.

The logging instrument is a metal cylinder, about 9 3/4 ft long and 3 5/8 in. in diameter, and is lowered into the well hole with a hoisting apparatus. Figure 3 illustrates the action of the subsurface instrument in detecting gamma rays. The lower portion of the instrument comprises the ionization chamber, which contains two insulated electrodes surrounded by an inert gas under high pressure. Normally no current will flow through the gas for any electrical potential between the electrodes. When, however, the chamber is exposed to gamma rays, ionization of the gas takes place and the flow of a small amount of current between the electrodes is permitted. The amplifier in the subsurface instrument amplifies this current, which is transmitted to the surface instruments for further amplification and automatic recording. The amount of the current flowing between the electrodes is proportional to the intensity of gamma-ray radiation. The gamma rays are very penetrating and will penetrate several thicknesses of well-hole casing and thus permit logging of cased holes.

Figure 4 shows a typical gamma-ray curve which would be obtained from the recording apparatus in the instrument truck. The curve comprises an automatic plotting of depth from a reference point against relative radioactivity of the various strata passed through in the well hole. The horizontal lines drawn at midpoints of the curve transitions indicate how points of change of strata are picked.

Applications

From the standpoint of water wells the gamma-ray curve can be correlated with known lithology and drillers' logs to:—

(a) Determine the exact limits of desirable water-bearing strata, suitable for tapping;
(b) Determine exact limits of strata it is desirable to case off;
(c) Increase capacity of existing wells by location of accurate limits of strata originally cased off (These strata could then be tapped by gun perforation.);
(d) Obtain logs of existing wells, for which no data exist, for purposes of correlation with new wells and identification of aquifers which have been cased off.

These data are of major importance in areas where deep wells produce from aquifers comprising separated producing zones at

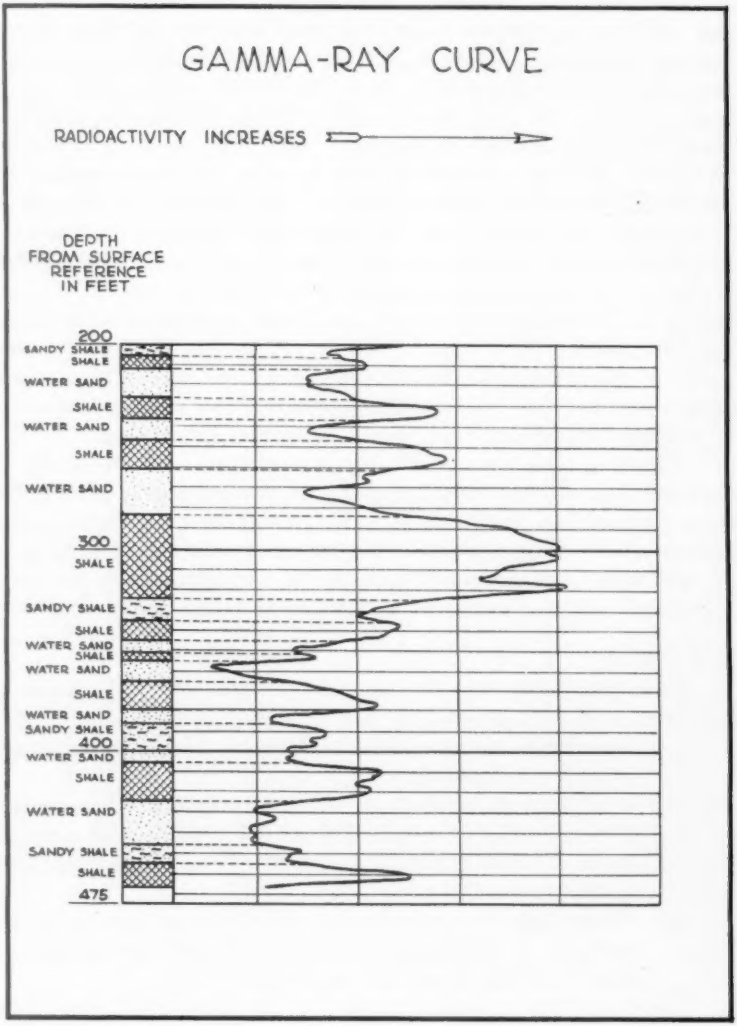
GAMMA-RAY CURVE
RADIOACTIVITY INCREASES
DEPTH FROM SURFACE REFERENCE IN FEET
200
SANDY SHALE
SHALE
WATER SAND
SHALE
WATER SAND
SHALE
WATER SAND
300
SHALE
SANDY SHALE
SHALE
WATER SAND
SHALE
WATER SAND
SHALE
WATER SAND
SANDY SHALE
400
WATER SAND
SHALE
WATER SAND
SANDY SHALE
SHALE
475

FIGURE 4.

several depths. It is, therefore, necessary to locate accurately the limits of the producing zones of good quality.

The importance of a means of obtaining data on existing cased wells is not to be minimized, if water-supply engineers will recollect that the only information available on many existing wells comprises that which is visible above the ground.

Electrical Well Logging

The electrical well log comprises curves of the electric resistivity and electrical potential of the strata in uncased well-hole walls and the fluids contained in these strata.

The apparatus for making these determinations comprises an electrode assembly, hoist and instrument truck. The electrode assembly, the lowering cable therefor, the hoisting apparatus and recording instruments are all carried in a truck illustrated in Figure 5. The recording panel of the truck is illustrated in Figure 6. The apparatus is illustrated schematically in Figure 7.

The traveling electrode assembly, which is lowered into the uncased well hole, comprises one or two current electrodes and a number of potential electrodes differently spaced. A typical electrical log is illustrated in Figure 8. The electric circuit is so designed that both the potential and resistivity of the well walls can be measured and recorded simultaneously on the same strip type of chart.

The data available from the electric log strip, when correlated

Fig. 5.—Electrical Well-Logging Panel Truck.
(Courtesy of Schlumberger Well Surveying Corp.)

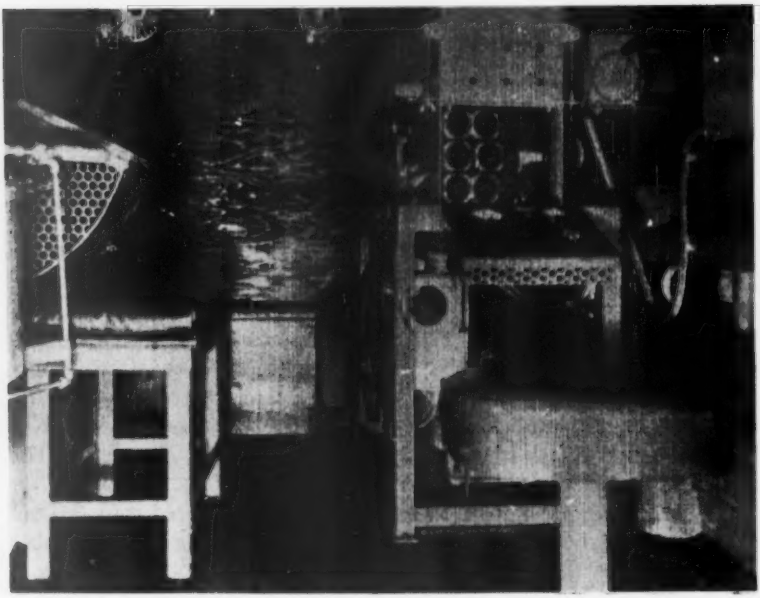

FIG. 6.—INTERIOR PANEL OF ELECTRICAL LOGGING TRUCK.
(Courtesy of Schlumberger Well Surveying Corp.)

with known lithology, can be interpreted to indicate the lithology of the well-wall formations and their relative permeability. In addition, the character of the fluids contained in the various strata can be deduced with varying degrees of accuracy.

The Resistivity Curve

Most limestones and other dense rocks and permeable formations containing fresh water have high resistivity values, in comparison with shales and clays and permeable formations containing saline water. Resistivity measurements are also affected by the character of the fluid in the well hole and by the diameter of the well hole. The degree of these latter effects is controlled by varying electrode spacing.

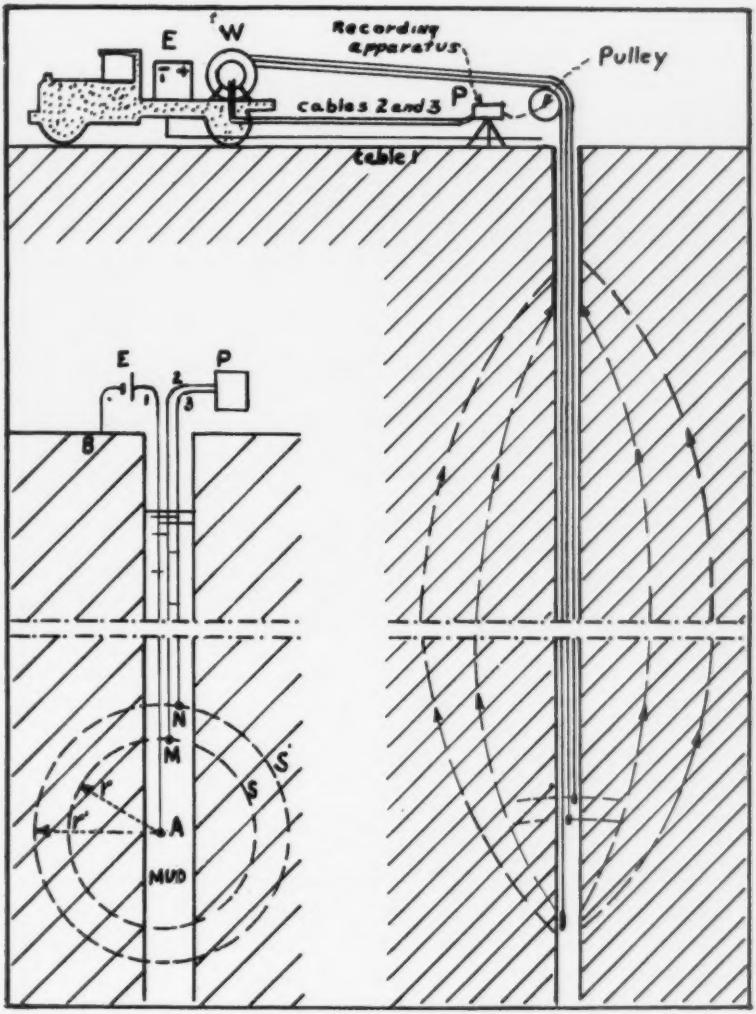

FIG. 7.—ORIGINAL SCHEME OF ELECTRICAL LOGGING DESIGNED BY CONRAD AND MARCEL SCHLUMBERGER.

(Courtesy of Schlumberger Well Surveying Corp.)

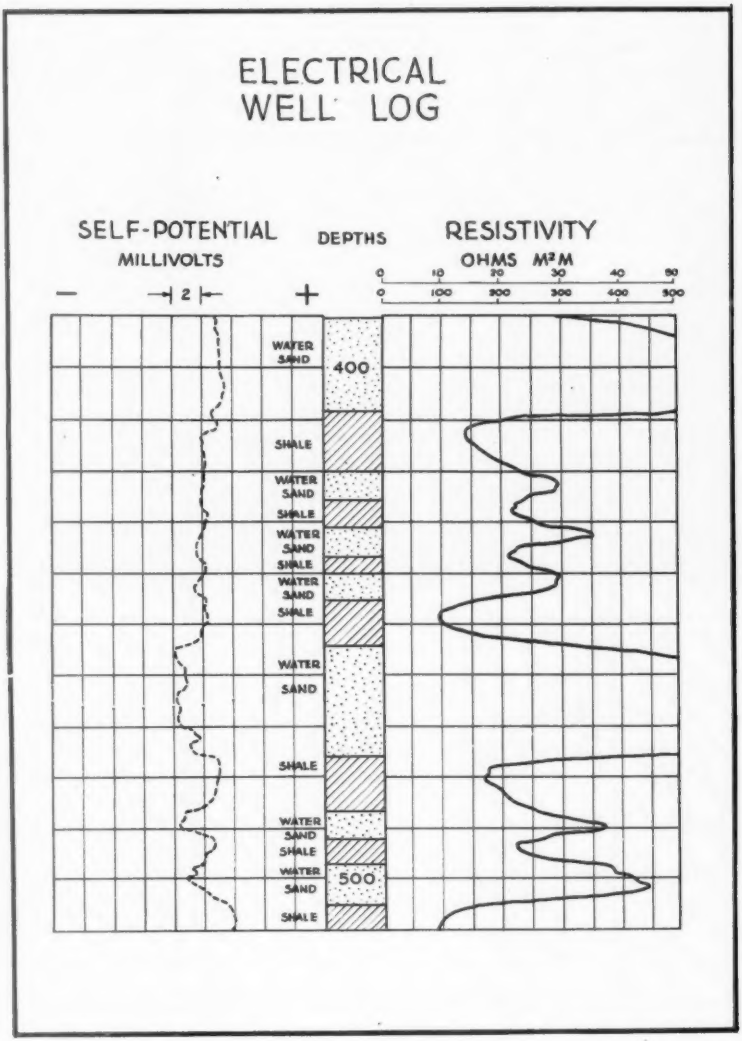
ELECTRICAL
WELL LOG
SELF-POTENTIAL
MILLIVOLTS
DEPTHS
RESISTIVITY
OHMS M²M
WATER SAND
SHALE
400
500

FIGURE 8.

The Potential Curve

The self-potential curve is often referred to as the "porosity curve". The porosity of the formation and the specific gravity and chemical character of the fluid contained therein all have varying degrees of effect on the self-potential curve. In general, conditions which would cause the bore-hole fluid to flow into the surrounding formation give a negative potential reading and flow into the bore hole produces a plus potential. The magnitude of potential difference gives indication of relative rates of flow.

Interpretation of the Electrical Log

The interpretation of the electrical log illustrated in Figure 8 is indicated by the classification of water sand and shale, and simulates a condition of relatively thin-bedded water-bearing zones, separated by impervious shale layers. In such a problem it would be necessary to perforate the casing or provide screen sections opposite the water-bearing strata and seal off the shales. In practice, the resistivity curve would be correlated with the drillers' samples and, if possible, with data available from other wells in the vicinity with respect to lithology and water quality. It is to be noted that the water-bearing sands are characterized by high resistivity, indicative of lithologic character and fresh water content, and by sharp breaks in the self-potential curve, indicative in this instance of relatively high permeability.

Applications

From the standpoint of wells for water supply, electrical logs made in the uncased bore hole provide the following data:—

a) Record of lithology of the wall rocks;
b) Location and relative porosity of permeable strata;
c) Indication of contained fluids.

Summary

1. Electrical and radioactivity methods for oil-well surveying have also been utilized in connection with ground-water supply development.
2. Radioactivity logging apparatus permits surveying of cased or uncased bore holes. The gamma-ray curve provides log

of well-wall strata when correlated with known local lithology. Combinations of gamma-ray and neutron curves are available to provide evidence for interpretation and correlation with known local conditions with respect to relative permeability of well-wall strata and amount of contained fluids.

3. Electrical logging apparatus permits surveying of uncased bore holes, providing curves of self-potential and resistivity, which can be correlated with known local lithology to provide log of well-wall strata and facts and evidence regarding relative porosity of permeable strata, character of contained liquids and relative hydrostatic heads in different producing zones.

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Discussion

William B. Duffy (North Andover, Mass.). Is this method very generally used?

John J. Baffa. Yes, it is quite prevalent in the West and Midwest.

Mr. Duffy. Oil drilling?

Mr. Baffa. Mostly oil drilling, but it has found considerable application in water-well development in the area where this service is normally available for oil wells.

Donald C. Calderwood (Nashua, N. H.). Have you any unit

costs regarding this type of a survey which would be applicable here?

MR. BAFFA. Yes. The cost usually has various component parts. There is usually a $100 service charge, plus five cents a foot for the logging operation, plus 15 cents a mile applied to the number of miles that the truck has to travel from its base of operations to the well and back again. Thus, for a 500-foot well the cost might run about 26 to 30 cents a foot. If you estimate drilling and casing to cost about $6, the logging operation would cost approximately 4% of the drilling and casing. But if applied to the total cost of a well installation —that is, including the pump, well house, and connected piping, fittings, meters, and so on—the cost would represent a very small percentage of the cost of the entire development.

WARREN J. SCOTT (Hartford, Conn.). What is the practical application? After you put down a series of wells do you go in and log them to see about placing the screens?

MR. BAFFA. You know exactly where your screens should be. In many cases, if you do not get your screens in the right places you may get colored water or bad water, and things of that nature. It is quite necessary, however, to correlate the operation with known conditions, because you cannot identify a stratum—that is, to be able to name it—just from a logging, but you can tell that it is the sand for which you are looking. Of course, the main application of the radioactivity log is in respect to wells already cased, about which you do not have logging information but on which you are familiar with the surrounding territory and know approximately what strata to expect, although possibly not at what depth they are. You can, by correlation of the radioactivity log in the well in question with radioactivity logs in other wells nearby, find the sand you are looking for and tap it.

GEORGE A. SAMPSON (Boston, Mass.). What is the minimum size of well?

MR. BAFFA. I believe they can get into a 3-inch casing with the electrical log. The radioactivity logging cylinder is 3 5/8 in. in diameter, so that I imagine the minimum would be about a 4-inch casing for that.

MR. DUFFY. Is this a comparatively new development?

MR. BAFFA. The radioactivity log was made available in 1940. The electrical log was much older than that; it goes way back to the 1930's—I don't know the exact date.

FILTER-PLANT OPERATION AT CAMBRIDGE, MASSACHUSETTS

BY FRED E. SMITH*

[*Read March 18, 1948.*]

IN APRIL of this year the Cambridge filter plant will have been in operation for 25 years. During this quarter-century 127 billion gallons of water have been filtered. The plant has been shut down for approximately two weeks during this period, as a result of pumping-station or distribution-system repairs. The longest shut-down due to plant repair or changes did not exceed eight hours.

Previous papers (1), (2), (3), (4) have been published in the JOURNAL of this Association, describing plant construction, enlargement and operating results through 1939. This paper will discuss plant operation from 1939 through 1947. Wartime experience with precaution against sabotage and difficulties with shortage and non-availability of personnel, materials and supplies will not be recorded, because the problems at Cambridge undoubtedly were similar to those of other cities during the war period. Reference will be made later to technical wartime problems and the methods adopted to overcome them, and increased consumption will be discussed.

RESERVOIR OPERATION

The Cambridge system of reservoirs was established in 1855, when Fresh Pond water was distributed to the city. The system was enlarged in 1887 by the construction of Stony Brook reservoir in Waltham and was completed when Hobbs Brook reservoir was placed in service in 1898. The present system of reservoirs has provided a water supply for the city for almost 50 years with certain changes. The principle change in reservoir operation occurred in 1923, when the gravity supply from Stony Brook reservoir was diverted at a weir chamber to flow directly to the filter plant. Fresh Pond water is pumped to the filter plant to supplement the gravity supply and any

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surplus water from Stony Brook reservoir overflows at the weir into Fresh Pond.

The severe droughts in 1940-41 and in 1947 caused excessive draw-down of all reservoirs—in particular, Stony Brook and Fresh Pond. The first is relatively small, having a capacity of 400 mil gal, and is maintained at low elevation because the reservoir has a comparatively large catchment area. A heavy rain or quick thaw causes a rapid rise in the reservoir elevation and overflow of water into the Charles River will result, if storage is not available for the runoff.

In similar manner, efficient operation of Fresh Pond indicates the desirability of maintaining the reservoir at low elevation, to provide storage for surplus Stony Brook water which otherwise would be wasted. Another reason is the infiltration of ground water into Fresh Pond when the elevation has been sufficiently lowered, as in 1944 to —2.4 ft and in 1947 to —2.0 ft. This supplementary water provides additional supply during periods of drought, thereby aiding maintenance of the required yield by the reservoir system. These general conditions dictate the procedure of reservoir operation, which consists of utilizing Stony Brook and Fresh Pond reservoirs to the maximum extent and maintaining the Hobbs Brook supply as reserve, to be used only as required by necessity. As Hobbs Brook reservoir has a small catchment area and fills slowly, this procedure has the added advantage of providing maximum time during which the reservoir can fill.

Raw water at the filter plant, therefore, is provided by the gravity supply, supplemented by Fresh Pond pumpage—a mixed raw water. In Table 1 is recorded a summary of average analyses of raw water for the past five years.

TABLE 1.—RAW-WATER ANALYSES

Year	Color (ppm)	Bacteria per ml on agar at 37°C.	Coliform organisms (M.P.N. per 100 ml)
1943	23	25	20.9
1944	26	21	13.4
1945	34	19	43.2
1946	27	15	24.0
1947	30	82	107.6

Little difference is noted in the record of color during the five-year period. The sharp increase in 37° bacteria and coliforms in 1947

was the prolonged effect of a very heavy rainfall in November of that year. Reservoir elevations were low and the runoff received little storage because of continued high consumption. The tabulated results show that the purification load on the filter plant generally is not excessive, with reference to the color and bacterial numbers. The water contains very little turbidity and odors are faint.

Microscopic Organisms

Stony Brook reservoir has been the principal source of microscopic growths during recent years, in this status replacing Fresh Pond as the most frequent offender. *Anabaena* grew in Stony Brook reservoir in 1940 and was readily killed with copper sulfate in dosage of 2 lb per mil gal. Very small numbers of *Synura* cause severe odor and taste in this reservoir, and in 1940 a growth of 8 standard units per ml required treatment. When *Synura* is present in the reservoir, the supply is shut off for copper-sulfate application, because the odor and taste of the water are intensified for 24 hours after treatment. With other organisms, especially diatoms, the reservoir is not removed from service during treatment. *Melosira* in the amount of 400 standard units per ml was eliminated with 2 lb of copper sulfate per mil gal in 1947 and this growth was replaced in a few days by a new aquatic infestation of *Dinobryon,* in numbers exceeding the growth of diatoms. Further treatment with 2.5 lb of copper sulfate per mil gal was applied to remove the new growth. *Synura* has never occurred in numbers sufficient to cause decrease in filter runs, but this effect has been manifested by other growths, especially the diatoms.

During the winter of 1944 a growth of diatoms occurred in Fresh Pond. The reservoir was ice-covered and bags of the algicide were suspended through the ice in holes at intervals of about 25 ft. The treatment of the reservoir was successful and was the first winter application of copper sulfate in the Cambridge reservoirs.

Coagulation and Sedimentation

The difficult problem of coagulation of Cambridge water has been stressed in previous papers and this condition remains unchanged. Stony Brook water containing fresh color coagulates poorly; filter runs are extended but maintenance of effluent quality is difficult. Con-

versely, stored water with little color yields an excellent effluent but filter runs are drastically shortened. The procedure of mixing the gravity and pumped supplies improves coagulation, because Fresh Pond water always is coagulated more readily than the gravity supply. The effect of temperature on color removal by coagulation is noted in Table 2, recording data of January and July, 1939.

TABLE 2.—EFFECT OF TEMPERATURE ON COAGULATION

Month	Color		pH		Alum (g.p.g.)	Temperature (°F.)
	Raw	Coag.	Raw	Coag.		
January	34	35	6.9	6.1	1.11	39
July	33	18	6.8	6.1	1.14	72

With raw water nearly the same in color and pH, and with similar alum dosage, no color was removed at 39°F., but at 72°F. nearly 50% of the raw color was removed.

Alum Equipment

The Hamblet dry-feed machines have continued to give excellent service. They have been operated since 1932 with only minor repairs. Application of the alum solution to the raw water is done with a four-inch, Universal, cast-iron pipe line. Daily flushing is necessary to remove inert material, which settles from the alum solution. In 1947 the line was dismantled and cleaned with a flexible sewer-cleaning apparatus. The previous hand-cleaning was in 1944.

During the war it was necessary to use alum containing 10% insoluble matter, in contrast to pre-war material with 0.1% insoluble content. In order to prevent rapid accumulation of inert material in the feed line, the alum solution was settled in a tank formerly used with abandoned solution-feed apparatus. Settlement of the sludge in the tank enabled dependable alum dosage of the raw water to be done, without interruption due to a clogged feed line.

Sedimentation

The sedimentation basins have a capacity of 1.5 mil gal. Detention period of the coagulated water is now less than two hours because of increased consumption. Basins are cleaned at three-week intervals in summer and at six- to eight-week intervals during cold weather.

Sludge depth is six feet when cleaning is indicated, representing about a third of the basin capacity. Some sludge of indeterminate volume is discharged by gravity into Fresh Pond, the bulk of the settled material being pumped to the sewer.

Filters

The Cambridge filters have been subjected to hard usage since the plant was first placed in operation. Inadequately coagulated water has placed an undue share of the purification load upon the filters. Increased demands for water by the city in recent years and a relatively small clear-water basin have necessitated almost continuous operation of 14 of the 16 filters. One filter has been out of service for several months, pending delivery of a 16-inch valve. As a result of these conditions, extensive repairs to the filters and their operating mechanisms could not be done. Clogged areas have developed in a few filters which will require attention. During the past five years, the number of daily washes was 21 and the period of service was 15 hr, with 5.7% wash water, all figures being averages. During this period the average alum dosage was 183 lb per mil gal. The effect of short filter runs and frequency of washing is reflected in the relatively large percentage of wash water. Used wash water has been returned to Fresh Pond since 1932 with no deleterious effect upon the reservoir. Algae growths have been very small. In earlier years the wash water was pumped to the sedimentation basins or discharged to the sewer.

Aerator

Cleaning of the white tile troughs of the aerator and painting of the room were done in 1947, after having been long postponed. Sluice gates had not been operated for an indefinite period and were forced open with difficulty. A complete plant shut-down was required in order to have one gate accessible for repair. Yellow organic stain was removed from the aerator tile with a solution of hydrochloric acid containing free chlorine. Walls and ceiling were redecorated and a long-existing leak in the wall was closed. This project restored the appearance of the aerator to its condition of 1923, when it was first placed in service. In plant operation the aerator releases a little carbon

dioxide, together with odor and taste to a certain extent. It is, however, interesting to plant visitors, being readily observed.

Corrective Treatment

Lime has been used for corrective treatment of the filtered water since 1930. The Wallace and Tiernan machine has operated dependably, although now out-moded. Its principal deficiency is production of dust, as the hopper is uncovered. Lime treatment has materially reduced the corrosive power of Cambridge water. No complaints of red water have been received for several years. Average lime dosage is 93 lb per mil gal and a pH of 8.8 is maintained in the plant effluent.

With the present installation, the lime solution is added to the filtered water at the entrance to the clear-water basin. It is planned to change the position of the lime feeder, to discharge the lime into the effluent of the clear-water basin. This change will create a difficulty in lime feeding, because the new location will require use of a long feed line, replacing the hose which now delivers the lime solution to the water. Cleaning of the hose is easily done by hand methods; a pipe line will present greater difficulty in cleaning.

Chlorination

After 22 years' service the original chlorinator was replaced by a new and larger machine. The old chlorinator was overhauled at the factory and has been installed to provide prechlorination of the coagulated water, if a study of this procedure indicates that it is worth-while.

The efficiency of disinfection has been decreased by the close proximity of lime- and chlorine-feed hoses, as these chemicals are applied to the filtered water. When the lime feeder is moved to its new position, the clear-water basin will then be available for detention of the chlorinated water at a low pH value. Chlorine dosage averages 4 lb per mil gal, with a residual value of 0.2-0.3 ppm at the plant. It is planned to procure additional scales for duplicate chlorine-feed apparatus. Valves have been installed in the feed line which will control the flow of gas from each pair of cylinders. Replacement of empty cylinders will then be done only by the day personnel.

Plant Effluent

Table 3 summarizes analytical results of the plant effluent for the past five years.

Table 3.—Average Analyses of Plant Effluent

Year	Color (ppm)	pH	Bacteria per ml on agar at 37°C.	Coliform organisms (M.P.N. per 100 ml)
1943	7	8.7	2	0.21
1944	4	8.7	1	0.06
1945	4	8.7	1	0.33
1946	2	8.8	1	0.53
1947	3	8.5	1	0.13

For the past four years effluent color was less than 5 ppm. The pH value was 8.7 or 8.8, except in 1947, when restricted lime dosage was necessary during the extended period of aerator repair. Normal hardness of the finished water is 45-50 ppm. However, in recent months the infiltration of ground water into the reservoirs has increased the hardness to 55-60 ppm. Alkalinity of raw and final waters has also increased. Effluent plate counts were very small and results of coliform tests were low.

Cost and Consumption of Water

Table 4 presents filter-plant cost data and average production figures for the period 1943 to 1947.

Table 4.—Cost and Consumption of Water

Year	Quantity filtered (mgd)	Total cost	Chemical cost	Chemical cost per mil gal
1943	16.51	$56,390	$21,232	$3.52
1944	17.11	58,535	18,841	3.00
1945	16.39	56,653	19,646	3.28
1946	16.31	52,649	16,314	2.74
1947	16.59			

The average volume of water filtered daily in 1944—17.11 mil gal—was the largest in the history of the plant. In August, 1944, maximum daily production was 20.57 mil gal and the average volume filtered daily was 19.28 mil gal. Cambridge experience in the maintenance of high consumption during the post-war period is similar to

that of many other cities. In the last pre-war year—1941—average production was 15.15 mgd, at a time when the defense program was in effect with accelerated industrial activity.

Laboratory

Complete redecoration of the plant office and laboratory was done in 1947. Rearrangement of some laboratory benches and apparatus has made available additional working space. Replacement of the rubber floor mats with asphalt tile has greatly improved the laboratory appearance and has facilitated cleaning of the rooms. Installation of fluorescent lighting will be done this year. Routine chemical and bacteriological control of plant operation continues. An interesting research project comprised a laboratory study of mixing, coagulation and sedimentation conditions, with reference to proposed plant expansion.

Personnel

Personnel changes occurred frequently after 1942. When the writer returned from military service in 1947, only two operators remained from the original staff. Replacements were inexperienced and one of the original operators was immediately appointed chief operator. Training of personnel was instituted and in the past year improved operation has been effected. A new policy has been established by which all changes in operation, plant repair, and maintenance jobs are done by day personnel, only routine operation being handled by the night crews.

Acceptance of the 40-hour work week by the City Council has established a five-day week for all filter employees. This change was effected without increased personnel. The working schedule was modified so that the shifts alternate at two-week intervals. New desks and installation of radiators have improved the working conditions and comfort of the operators. A new locker room and shower bath are planned.

Retirement of the General Superintendent

After 29 years of faithful service to the Water Department and city, former Mayor Timothy W. Good retired as General Superintendent on May 31, 1947. Major projects completed under Mr.

Good's supervision included construction and enlargement of the filter plant, addition to the pumping station and re-lining of Payson Park reservoir, together with many distribution-system changes. Mr. Good's term of office exceeded that of any of his predecessors who have held the position since 1865, when the Water Department was established.

Future Plans

Completion of the painting and re-decorating program will be done during the current year. The halls, office and laboratory were painted in 1947, and new flooring was laid. Rooms will be decorated in different colors, offering a pleasing contrast in passing through the building. A most worth-while project is the establishment of a class room with seats, exhibits, flow diagrams and modern lighting. This installation will make possible the presentation of a more complete and effective demonstration of purification of the city water supply.

The installation of flocculators will fulfill a long-standing need, because no mixing facilities are presently available. Further changes in the sedimentation basin will provide longer detention of the coagulated water. The future plans will modernize the plant in accordance with current standards of water treatment. They promise that the second quarter-century of operation of the Cambridge plant will be most interesting.

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HIGHLIGHTS OF PRIVATE WATER COMPANY OPERATION

BY ALLEN M. SYMONDS*

[*Read March 18, 1948.*]

WE HAVE throughout the United States and here in New England a corporation known as a private water company. Such companies are not common and, as compared to the total number of existing water-works plants, mostly owned by municipalities, are considerably in the minority.

Back in the late 1800's many private water companies were started locally, being sponsored by public-spirited members of the community, who saw the need for a common water system. Financing of construction was done locally, through money obtained from banks on mortgage notes and by the sale of stock to the public. As time went on and towns grew into cities, the local citizens, responsible for the operation of these companies, often found it difficult to finance needed improvements and this circumstance encouraged the cities to purchase the plants and use them as a nucleus for further expansion.

Again looking into history we find that during the 1920's there commenced a merger movement of many of those private companies which had not been taken over by the cities or towns. The result of these mergers was a grouping of local companies into larger units as a means of improving financing and management. History seems to have justified this movement, in that it has become possible under the combined power of affiliated companies to obtain money through broader channels of finance and to keep abreast of needed improvements.

Water companies were commonly financed by bonds and stock —often about 50% of each—mergers being brought about through purchase by a holding company of the stock of the local company, the bonds or mortgage notes remaining with the banks or original investors. Later on, as general conditions favored a complete re-

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financing, contracts were made, largely with insurance companies, for the purchase of all bonds and, because of the large issues involved, more favorable interest rates than were originally in effect became possible.

These mergers, while not in any way affecting the financial structure of the individual companies, greatly strengthened their position for obtaining new money for expansion.

The merger movement did not necessarily affect all water companies but probably, as a general rule, corralled only the weaker ones, while the stronger ones, being able to battle out their troubles alone, preferred to remain a single unit, as in the case of the Pennichuck Water Co. in Nashua, N. H.

It so happens that the writer is employed indirectly by the Northeastern Water Co., which is a so-called holding company and, at the present time, the largest private water corporation in this country, controlling many subsidiary water companies throughout the eastern United States. The writer's particular territory includes 7 companies located in southern New England with a total capitalization of $2,096,000, which have in combination 147.6 miles of mains, 9,131 services and 711 hydrants, and serve a population of 56,000, which paid in 1947 through water bills $348,000. As compared to many of your cities this is not a large water works. We do have one unique phase of operations, however, in that our territory is approximately 200 miles in diameter and extends into four states.

It has often been said that a public utility has no competition. While this may be theoretically true, we do have competition from neighboring cities and towns, one of our principal competitors being the city of Worcester, which sells water for about one-half of what we do in Millbury, Grafton and Oxford. This is always a source of woe to our customers, who frequently remind us of it. I shall not attempt to analyze the reasons for these particular variations but should like to describe in general some phases of private company operation, as compared to that of a city- or town-owned plant.

In the first place, our physical problems—or you might say mechanical operations—are identical. The staff of outside employees performs exactly the same service as do city water-works employees. Our pumping, other operating routine, and maintenance of the system

are the same. In the lower brackets it makes little difference, from the employee's standpoint, whether he is working for a private water company or a municipal plant. As you get into the higher brackets of employment, however, the private company employee has the advantage of being free from political influence. The manager is sure of his job, provided he keeps in line with company standards, and in the larger utilities there exists an element of competition between the various company managers, which tends to keep them on the alert for promotion. Occasional contacts with top officials located in cities like New York, Boston or Philadelphia stimulate interest, allow an interchange of ideas and broaden the manager's point of view.

It may be concluded from these remarks that the employee of a private company has some advantages and, in my opinion, these advantages are a definite factor in favor of private company operation.

A privately owned water company must live on its income. It must also make new investments in plant and property in accordance with sound business principles; it has no power of taxation, and it has never been favored by any government grant or subsidy. Its operations are constantly under the watchful eye of the Department of Public Utilities and it contributes a considerable portion of its income to local, state and federal taxes. Under these requirements I sometimes wonder how a private water company, doing business side by side with municipal plants, has been able to survive the past 15 years of New Deal competition.

A private water company is limited in its investment policy by the potential income from that investment. Public Utility Commissions and engineers have ruled that it is unwise to spend money on new plant unless a gross return of 15% is realized, either from revenue-producing customers or from decreased operating costs or maintenance. Because of the limitation of income to receipts from water bills, without any power of assessment or taxation, the private water company finds it difficult to satisfy many people living in suburban areas, who would like extensions of the water system. Although this is sound business, endorsed by money lenders, and in the long run necessary if good credit standing is to be maintained, it reacts against the local water company, especially when political pressure is brought to bear and its proposals are defeated.

A town, with its power of assessment, taxation and town meeting, and without control from any governing commission, can often run through some politically pressured extension, which, from a purely business standpoint, would be entirely unjustified. W. P. A. and direct government grants to municipalities for the construction of new property seem in the long run to be economically unsound and are certainly unfair competition to privately owned plants, which were and still are operating under the capitalistic system, where one side of the ledger has to balance with the other.

We are all in the same business, whether municipally or privately owned, our objective being the delivery of good water to all inhabitants of the community. The rules, however, are somewhat different and reflect their differences in the water rates. The water bill to the customer of a private water company includes interest on the plant investment, retirement provision, which is equivalent to amortization, and local, state and federal taxes—items, as a rule, not included in the water bills of a municipal plant.

In looking ahead into the next few years we feel as though a program of unusual plant expansion might take place. Real estate promoters have purchased tracts of land, built streets and, of course, asked for water service. As many of these developments are non-revenue-producing at the time of their inception, our water companies have felt reluctant about investing money in main extensions—bankers will certainly not loan money on indefinite futures—so the projects have in some cases become stalemated, as land is difficult to sell without water and the company will not install pipes without houses. In an attempt to overcome this situation, we have prepared a more or less standard agreement, which provides for the extension of mains into new territory by the water company, the sponsor of the project to deposit with the company the total cost of the extension and, upon construction of new houses or the connection of existing ones, the money to be returned to the sponsor as each house is connected and in accordance with the terms of the agreement. If the development goes through to completion as originally planned, the sponsor gets all of his money back. In any event he is reimbursed in proportion to the number of houses built. This seems to be the fairest solution to all concerned. Some real estate contractors, who are operating on a

shoe-string, have found it impossible to make the required deposit for water-pipe extensions and other promoters have sold their lots for what they could get for them, leaving the individual purchasers to shift for themselves. Thus the agreement, although apparently the fairest way out, has not worked in all cases.

In municipal operation, on the other hand, it is the practice in many towns to expect real estate developers to install water mains in their private streets, which, upon acceptance by the town, will include the mains laid therein with no reimbursement for their investment. In other cities no definite policy exists, but if the development appears to have a reasonable chance of success, the city will lay its mains through private streets as an encouragement for real estate construction. Sometimes a few boxes of cigars or more potent persuaders, along with political influence, can stimulate interest in water-main extension. Municipal plants can also assess real estate on a foot-frontage basis or make up a construction deficit out of the general tax fund.

Private companies must construct and own their plants outright, if they are later to be allowed to receive revenue from them, and the revenue received must be sufficient to cover all charges.

It has been the writer's experience that the water bills rendered to consumers of a private water company are usually higher than those rendered by a neighboring municipal plant. Most consumers look upon this with suspicion and usually accuse the water company of being an economic royalist or something worse. An understanding of the rules, however, governing private company operation should reveal the fact to a customer that he is paying 100% of the cost of the service, including taxes, and this practice seems to me like sound business.

People in general are opposed to regulation and I am no exception. My dealings, however, with the Public Utilities Commissions have been very pleasant and I frequently call on them for guidance in clearing up controversial questions. In my estimation, a great service would be rendered to all cities and towns, if their water departments could be placed upon an independent basis, apart from other town affairs, with their operations self-supporting and under the jurisdiction of the D. P. U., the same rules governing as with privately owned utilities.

The above remarks may have created an impression that private water company operation is a model to be admired by all. This is not entirely so, as evils can exist, including padded management fees by top officials, too great a drain on surplus by dividends, and artificial inflation of plant values.

In our particular case, all charges against the local companies by the management company are made on a time-sheet basis, every official from the President down keeping a time sheet and charging out his time and expenses as actual service is performed. Under the influence of the P. U. C. as existing today, any of the evils of private operation mentioned could not long endure.

It has sometimes been stated that "the plant of a private company is never paid for". This may be true from the viewpoint of the customer, who, if seeking lower water rates, is confronted with the necessity of providing a rate of return upon the value of the plant. The bonds may be completely amortized by the owners of the property but this has no bearing upon the value of the investment, which is based upon the cost of the plant less depreciation.

Probably the outstanding difference between a privately owned and a municipal plant is in this question of amortization, plant value and return on the investment. I think this difference can best be illustrated by comparing two pieces of real estate, lying side by side, one being occupied by the owner and the other by a tenant paying rent to a landlord. In the first property the owner, residing in his own house, in addition to paying carrying charges, has invested sums of money from time to time in the mortgage and eventually owns the property free and clear, with no further need for interest charges. In the second instance, the tenant is theoretically paying only the carrying charges, including maintenance and depreciation, and never amortizes the mortgage. The owner may pay off the mortgage, if he is financially able and so inclined, but this does not relieve the tenant from paying sufficient rent to cover a rate of return on the fair value of the property.

The first instance can be compared to municipal operation, where the people, generally through taxation, have either paid for a portion of the original plant or amortized it completely. The second instance can be compared to private company operation, where the water takers

are not interested in amortization but, through their water bills, rent the facilities and service of the private company.

There are many of us in this room who have accepted the responsibility of home ownership and there are probably just as many who rent, preferring to let the landlord worry about amortization, maintenance, etc. From a purely financial standpoint it is controversial as to which course is the best to pursue and I shall certainly not attempt to settle the question in this paper.

Although much in the minority in numbers, it is my opinion that the water companies, as they are now being operated, present an economically sound business—a part of the backbone of our capitalistic system—and, in their payment of local, state and federal taxes, are bearing their share of the burden of the tremendously increased cost of government throughout the nation today.

Discussion

Donald C. Calderwood (Nashua, N. H.). This paper has been quite different from the usual run of papers that apply to practically all plants or to systems which have various types of equipment in their plants. It applies very directly to the privately owned companies, which are in the minority, as Mr. Symonds says, in this New England area, although in some areas they exceed by far the municipally owned plants.

William B. Duffy (North Andover, Mass.). I see that the valuation is a little over $2,000,000. Are those 147 miles of mains in seven complete installations?

Allen M. Symonds. That is right.

Mr. Duffy. How did they arrive at the two million valuation?

Mr. Symonds. That is the amount of money that we have on our books as the cost of the plants. Of course that includes mains, pumps and the whole thing. It is simply built up through the past years as the cost of the plants.

Mr. Duffy. It has nothing to do with the present value, then?

Mr. Symonds. No; that is cost, or supposed to be cost.

Mr. Calderwood. I think you will find that most commissions insist upon carrying the amounts on the books as at cost, regardless of what the present valuation may be, and in fixing the rates cost

less depreciation is taken, rather than replacement cost less depreciation. Replacement costs for the most part are not considered at the present time, thanks to the New Deal influence.

JOHN F. MCDERMOTT (Boston, Mass.). Do you pay real estate taxes on the two million—that is, on the water mains, pumps and everything?

MR. SYMONDS. We pay two types of taxes in our town: the real estate tax on buildings, and so forth, and what is called a personal property tax on the water mains. Standpipes, I think, come under that too. It is all either personal property or real estate.

MR. MCDERMOTT. The water mains in the streets, then, would be under the personal property tax?

MR. SYMONDS. Yes.

HAROLD W. GRISWOLD (Hartford, Conn.). Would you say that, if your system were publicly owned, there could be a reduction in water rates of approximately one-third? That is, surplus, dividends, the federal tax and some part of the local taxes would tend toward the reduction of rates, while the operating expenses under public operation would undoubtedly be increased and there would be a still further increase for the retirement of bonds. Would the net of those decreases and increases probably run around a third?

MR. SYMONDS. I think that is true, Mr. Griswold. The taxes may be a little bit misleading. I have a few figures here on hydrant rentals versus taxes. We received in 1947 $48,621 in hydrant rentals and public fire protection; we paid in local taxes $46,700, so that one almost offsets the other. Of course, the municipal plant definitely would save the cost of the federal taxes, as it would not pay any federal taxes. The dividends and interest and the surplus, as I said before, are 5 1/2%. If they financed the whole thing for maybe 3%, they would save something there. So that they might operate more cheaply than the private company, although they would not be supporting the federal government, as we are at the present time.

A MEMBER. On the extensions, how much do you return per house or per connection?

MR. SYMONDS. I thought that question might be asked, so that I have a figure here to show what our formula is. We start off with the average domestic revenue from a house, and we shall assume that

an extension has been put in and a house has been built on that extension. The average revenue from that house in this particular case is figured at $29 a year. We have an operating ratio of 48.7% in this particular company, which means that it costs us that much to operate the plant. That includes taxes, depreciation reserve and local taxes, but not federal income taxes. Thus, if we take 48.7% of $29, it amounts to $14.12, which leaves us $14.88 out of the $29. Then we have federal income taxes of 23% of our net income, which amounts to $3.42. We deduct that from the $14.88, which leaves us $11.46 in this particular case. We capitalize the $11.46 at 6%, which gives us $191. Then we subtract the cost of the new service and the meter —estimated to be $55—which leaves a refund for the sponsor of the project of $136, which in this case is 4.7 times the revenue received from this house.

THE MEMBER. Do you have any time limit on that—ten years or anything like that?

MR. SYMONDS. Yes, we have a time limit of ten years today.

THE MEMBER. Thank you.

MR. SYMONDS. That time limit can be varied. Some go twelve years, but we try to make the average about a ten-year limit.

MR. CALDERWOOD. In other words, you find in this particular case that you can afford to spend for those additions to plant $136 in pipe extension for each new customer?

MR. SYMONDS. Yes.

THE MEMBER. What guaranty is there that they will pay the $29? Suppose they fall below; do you take that chance?

MR. SYMONDS. We take that chance.

THE MEMBER. Suppose they pay only $15 or $20, instead of the $29; where does that leave you?

MR. SYMONDS. We take that chance. That is over all. If a project has gone through, 25 houses may be built and the average will come out, in this case, $29. There may be some which will pay $22 or $23, and some others will pay $35, but we have an average of $29.

METHODS OF CUTTING CAST-IRON PIPE

BY SHERMAN L. ROGERS*

[*Read April 21, 1943.*]

THERE are several ways of cutting cast-iron water pipe, but practically all except one have the disadvantage of being either slow or uncertain, when pipes larger than 16 in. in diameter are to be cut in a trench.

Probably the oldest method is to mark the pipe, where the cut is to be made, with a diamond-point chisel and then attempt to crack the pipe by driving chisels and wedges into the resulting V-shaped cut. If the pipe is marked all the way around, this method is usually satisfactory, but it is quite difficult to chip the underside of a pipe of any size and the tendency is to take a chance on the pipe's breaking square without completing the cut. To remove a section of a 42-inch pipe in this way may take eight or ten hours, since it will be necessary to make two cuts and to waste, as a general thing, at least three feet of the pipe. On 4-, 6- and 8-inch pit-cast pipe this method works very well, but the harder centrifugal pipe is likely to be more difficult to cut with diamond-point chisels.

Wheel pipe cutters, similar to the wheel cutters used by plumbers to cut ordinary wrought-iron pipe, are available to cut cast-iron pipe in the smaller sizes, but we have not found this method very successful where all the sections of pipe are firmly home.

The Strickler pipe cutter is a cutting device, one part of which is bolted around the pipe and the other part, carrying one or two milling tools, revolves in a raceway in the first or stationary part. On the small sizes, a ratchet handle, operated by one or two men, turns the revolving section and a star-fed cutting blade is automatically fed into the pipe, milling out a strip of metal about 1/4 inch wide. When two cuts are made, the section between them can be lifted out without wasting any of the pipe. On 42-inch pipe this machine is quite heavy and even with a crane upwards of two hours are required to set it up.

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We recently made two cuts with such a cutter in 42-inch cast-iron pipe that had a wall thickness of nearly 2 in. In this particular case the machine was driven by an air wrench and the cutting time was slightly over two hours per cut, with another three hours required for the installation and removal of the cutter. The total time required to cut out a section was approximately seven hours.

The cost was as follows:

Rental of cutter, including freight	$124.71
Labor:	
7 hours, foreman	10.85
28 " , labor	32.20
Rental of air compressor	7.00
Rental of crane, 4 hours	50.00
Total cost of removing section of pipe	$224.76

About the same time that these two cuts were being made, another method, known as the Oxyarc cutting method, came to our attention. It was so highly recommended that it was decided to try it out on two remaining cuts to be made in connection with this job.

According to the manufacturer's catalogue, the cutting speed in cast iron of this thickness should have been 2 in. per min, or about an hour per cut. However, probably because of inexperience on the part of the operator, the over-all time for the two cuts was about four hours. The cost to the Water Bureau was as follows:

Rental of welding machine and welder	$ 84.00
Labor, 2 hours	2.30
Foreman, 1 hour	1.55
Crane, 1 hour to remove section of pipe	12.50
Total cost of removing section of pipe	$100.35

From this it can be seen that there is a very favorable price differential in favor of this method of cutting and, what is often more important, a distinct saving in the time that the main has to be shut down.

The Oxyarc cutting method consists primarily of a special rod

holder, which is connected not only to a welding machine but also to a tank of oxygen. The rods used are hollow, mild steel rods with a special outside insulating coating. An arc is struck in much the same way as in welding and then the oxygen is fed through the hollow rod, right into the arc. This raises the temperature at the tip to something like 10,000°. At this temperature the cast iron is rapidly oxidized and blown out, partly as iron oxide and partly as molten metal. The high temperature is so localized at the welding tip that the pipe is barely warm two inches away. This method requires less skill than ordinary welding, because the rod is drawn across the work and no attempt is made to hold a constant arc length as in welding. The demand on the welding machine varies with the kind and thickness of the material to be cut. For 2-inch thick cast iron, about 225 amperes at about 25 volts and oxygen at 40 to 65 lb pressure are required. Either a direct-current motor generating set or an alternating current transformer may be used as a source of power. The Oxyarc method of cutting cast-iron pipe is illustrated in Figure 1.

A pipe, full of water, can be cut as well as a dry one, except that steam interferes with the operator's vision and must be blown away. The biggest item of expense, if you have your own welding

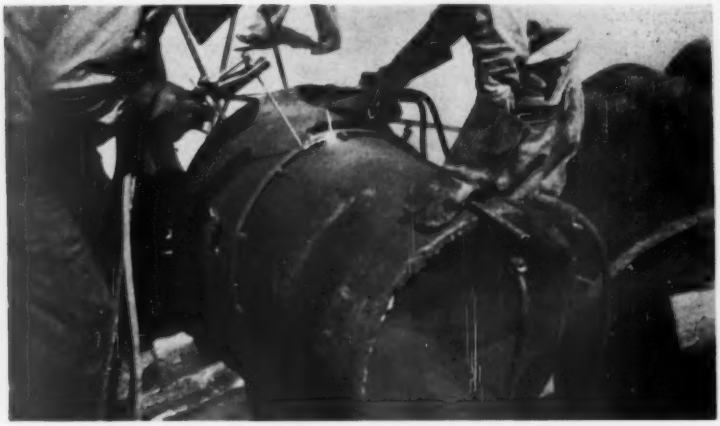

FIG. 1.—CUTTING CAST-IRON PIPE BY THE OXYARC METHOD.

machine and operator, is the cost of the rods, which is considerably more than that of ordinary welding rods, and apparently more are used for each inch of cut. It is estimated that it costs about 71 cents per linear foot of cut to cut cast iron that is 2 in. thick. This cost is divided about as follows: cutting rod, 59.4%; oxygen, 18.2%; labor, 21.2%, and current, 1.2%.

Several other water departments are reported to be using this method, notably New York, N. Y., and Manchester, Conn.

Cast-iron pipe has also been cut with oxy-acetylene, with not too satisfactory results, since the ends of the pipe are apt to be jagged and covered with beads of melted metal. It is also possible to cut pipe with a regular welding machine, together with regulation welding rods, by reversing the leads to the work and taking off metal, instead of putting it on as in welding. This is the most tedious method of all. For speed and efficiency, the Oxyarc method seems to be the best development to date.

OPERATION OF THE SLOW-SAND FILTER PLANT OF THE METROPOLITAN DISTRICT, HARTFORD, CONNECTICUT

BY ALEXANDER J. MINKUS*

[*Read April 21, 1948.*]

The slow-sand filter plant at West Hartford is the major element in the purification process employed by the Hartford Metropolitan District. Of the 31.5 mil gal that made up the daily average consumption of the entire District during 1947, 30 mgd came from this plant. The remainder was drawn from the former East Hartford reservoirs, located on the east side of the Connecticut River, where the treatment process is simple chlorination, with no filtration.

The effluent of the West Hartford filters supplies the seven member towns of the District—that is, Hartford, Bloomfield, Newington, Wethersfield, Windsor, East Hartford and Rocky Hill—and, in addition, non-member West Hartford. It is estimated that the population served in 1947 was 312,000. The range in the daily consumption varied from 21.0 to 37.4 mil gal.

The main source of the raw water for the filter plant is the Nepaug Reservoir, located 8 miles west of the plant. This is to be supplemented soon by the newly constructed Barkhamsted Reservoir, back of Saville Dam. In the immediate vicinity of the filter plant are five small reservoirs, four of which serve as reserve and emergency supplies and the fifth is employed to produce hydro-electric power for exclusive use at the filter plant.

The waters obtained from this system of reservoirs have the characteristics that make them well suited to the slow-sand method of filtration. In the past 26 years the average raw-water color was 22, the turbidity 2, and the total bacteria count at 20°C. 120 per ml.

The treatment process at present consists of three parts—aeration, slow-sand filtration and chlorination—but this has not always been the case. Prior to 1941, only aeration and simple filtration were used,

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the aeration being discontinued in the winter time. Slow-sand filtration alone was sufficient to produce an effluent that met the requirements of the U. S. Public Health Service at all times, except in the year immediately following the construction of the plant.

In 1941 four new filter beds were constructed and, because of heavy consumption, they were put into service at once, before the sand had time to ripen enough to become a satisfactory bacteriological filter. It was, therefore, necessary to resort to chlorination to produce a safe effluent. Soon after, the war started, so chlorination was continued as a precautionary measure. Now the filters are running at peak capacity a great portion of the time and the U. S. Public Health standards could not be met 100% of the time without chlorination.

The first step in the treatment process takes place in the aerator —an open, circular reinforced-concrete basin, 40 ft in diameter, into which water falls, after first having passed through a series of center jets, or slotted orifices spaced around the rim of the pool. In the past, it was necessary to shut off the aerator in the fall to prevent sudden and large increases in the lost head, resulting from air binding in the filter sand. In 1936 a program of sand washing was started that kept the sand in a cleaner condition than had been the case previously, with the result that the aerator could be kept running all winter without apparent detrimental effects.

The effluent of the aerator supplies 10 of the 14 filter beds, the other four being supplied with unaerated water directly from the supply mains. Twelve of these filter beds have filtering areas of approximately 1/2 acre, and two are of 3/4-acre extent. The 1/2-acre beds are arranged in groups of four around three regulator houses and the two 3/4-acre beds have a common regulator house. The regulator houses contain the necessary piping, gauges and control equipment for regulating the flow through the beds and, in addition, provide a means of access to the interior of the beds.

The groined-arch type of construction was used in the design of these filters, the arches being supported on concrete piers 20 in. square and 13 ft on centers. The underdrainage system consists of half-round tile laterals in each bay, connected to a central main drain extending the length of the bed. The tile laterals range in size from 12 in. at the main drain to 6 in. at the far end. The main drain is of

rectangular cross-section, 24 in. wide, and varies from 9 to 24 in. in depth.

The filtering material consists of 12 in. of gravel, overlying the drainage system, and 27 in. of sand on top of the gravel. The sand has an effective size of 0.32 mm and a uniformity coëfficient of about 2.0.

The biggest job at the plant is that of keeping the 7 1/2 acres of sand in a clean condition. There are three supplementary methods currently in use to do that—namely, harrowing, washing with a mechanical washer, and a process that is locally termed "re-conditioning".

Harrowing is the first and simplest process used. Depth of water over the sand is 6 ft in the ten oldest filters and 7 ft in the four new ones. When the lost head approaches 6 ft in one case or 7 ft in the other, the filter is emptied of raw water and the sand is allowed to dry overnight. The next morning a small tractor and an ordinary spike-tooth harrow, such as any farmer might use, are lowered to the sand surface. The steel spikes of the harrow are 6 in. long and are made to penetrate into the sand to their full depth by the weight of a couple of two-inch planks, tied to the frame of the harrow. The harrow is dragged back of the tractor until the entire surface of the filter has been traversed. This process breaks up the gelatinous film, that had caused the high loss of head, and mixes the material with the clean sand underneath.

The filter is then refilled slowly with a reverse flow of filtered water, taken from the effluent line of an adjacent filter. The rate of reverse flow for a bed of 1/2-acre area is usually 1/2 mgd. In the terminology of the rapid-sand filter operator, this is approximately 1/60 gal per min per sq ft. When the depth of water over the sand has reached about 6 in., the raw-water inlet is opened and the bed is filled rapidly and then placed into service.

A filter that is harrowed is out of service for 24 hours. If pressed for time, the process can be shortened to 18 hours. The time required to do the actual harrowing is only one hour for two men and the tractor, the other 23 hours being spent in draining, drying and refilling. In previous years, this job was done by a gang of men using hand rakes, because it was thought that heavy mechanical equipment, such

as a tractor, would compact the sand unduly. Experience has shown that this is not the case.

The rate of filtration in a harrowed bed is gradually increased from a starting rate of 1 mgd per acre to the maximum rate of 6.0 mgd per acre in the course of several days. The slow rate of increase prevents the entrainment of air amongst the sand grains some distance below the surface. A filter that is put into service in this manner may have an initial lost head of only 1/2 ft at the average rate of 4 mgd per acre, but the same filter is likely to have an initial loss of 2 ft if started immediately at 4 mgd per acre.

Each filter is harrowed five times before it is subjected to the next process. In that time the total volume of water filtered averages about 700 mil gal and the filter has been in service 9 to 12 months. It is then necessary to remove some of the dirt which has been mixed with the sand.

The machine used for that purpose is essentially a tractor with a gasoline-engine drive, carrying two pumps and a suction box, in which there is mounted a washing head. The washing head consists of a horizontal length of 2-inch iron pipe, 5 ft long, to which are attached, at right angles and pointing downward, 30 bayonet-shaped steel teeth. The teeth are hollow and have several small orifices in the lower end. They can be readily detached from the 2-inch manifold and there are available sets that are 8, 10 or 15 in. long. In effect, the washing head is a large steel rake, with tines that are either 8, 10 or 15 in. long, mounted in the lower part of an inverted steel box, which serves as a suction chamber for one of the pumps.

To use the machine, the water over a filter is drained to a 2-foot depth and the washing machine is placed on the sand surface by hoisting equipment, located over the entrance bay of the filter. The suction-box and washing-head assembly, mounted on the tail end of the tractor, is lowered until the teeth of the washing head penetrate into the sand practically to their full length. One of the pumps mounted on the tractor picks up the relatively clean water that is over the sand surface and discharges it into the hollow teeth. This water, jetting out through the orifices in the lower end of the teeth, causes an agitation of the sand grains and thereby separates the dirt from the sand. The second pump of the machine sucks up the dirty water, resulting from this

stirring action, and discharges it out of the filter bed through a 3-inch rubber hose line, trailing back of the machine and floated by means of cork floats. The entire machine is moving forward slowly while this takes place.

To reach the areas between piers it is necessary for the machine to travel at right angles to the original path. Teeth of greater length are inserted into the washing head after every pair of passes, so that, by the time a filter is considered clean, 8 passes have been made over its surface. Because of the tremendous drag on the machine, it is geared down to travel about 5 ft per min. With work proceeding at this slow rate, three shifts in 24 hours, 10 days are required to wash one filter of 1/2-acre area.

With 14 filters to be washed, two of which are 3/4 acre in extent, at least 150 working days are required to wash all of them. The loss in plant capacity during the washing program makes it essential to schedule the work for the winter months, when demand on the plant eases to some extent. It generally requires somewhat more than the 150 days to wash all the sand because of break-downs in the machine. Many moving parts are under water, where lubrication is difficult, and, moreover, the mixture of sand and water enveloping the lower portion of the machine is an excellent abrasive. But with proper maintenance the machine can be depended on to do the job; it has been doing it for 15 years now.

However, this type of machine has its limitations. Even with the use of 15-inch teeth—the longest that it is practical to employ without overloading the driving mechanism—the sand is washed to a depth of only 12 inches. Below that level, sand gradually becomes impermeable, due both to compaction and to dirt. To take care of that condition, resort is made to the so-called "re-conditioning" process once every seven years for each filter bed. There is no magic in that 7-year figure. Because of limited capacity in equipment and limited labor supply, only two filters could be re-conditioned in the winter months and, since there are 14 filters, the seven-year cycle naturally followed. It appears to make a satisfactory period.

The re-conditioning process is one of picking up all the sand above the gravel, washing it in the Nichols type of separators, and replacing it to its full depth. In preparation for this work, the filter is com-

pletely unwatered, including the underdrainage system. The sand is picked up, under present operating conditions, by hand labor. Four hydraulic ejectors are placed on the gravel and eight men shovel the sand into the steel hoppers which form the upper portions of the ejectors, taking care not to include any underlying gravel. At the bottom of the hoppers the jet formed by a pressure of 40 to 50 lb of water on a 5/8-inch nozzle picks up the sand and transports it through a 3-inch rubber hose-line to a pair of Nichols separators operating in tandem, two ejectors to a separator.

A Nichols separator is an enclosed steel tank, the upper two feet being cylindrical in shape and the lower two feet cone-shaped. In the lower portion is a quick-opening disc valve for removing the sand and the upper portion contains a pipe for skimming off dirty water.

The mixture of sand and water flowing from the ejectors enters the upper portion of the tank with a velocity of about 5 ft per sec and strikes a steel baffle plate. The sand settles to the lower cone and is discharged through the disc valve, while the dirty water is removed from the top of the machine by a 3-inch rubber hose-line, which carries it to a sewer outside of the filter.

The discharged sand drops directly into another hydraulic ejector of large capacity and is transported to a second pair of Nichols separators for another wash. The effluent of these separators contains just enough water mixed with the sand to make a viscous fluid, that will discharge from the end of a 2-inch rubber hose directly upon the gravel. The hose can be readily moved by the attendant to effect the placement of the sand in the desired place and depth. For locomotion the separators are mounted on small cast-iron wheels, that rest on planks lying on the gravel surface. It requires 6 or 7 men to push a separator into position for another day's work.

The re-conditioning process is a slow and tedious job. It takes 12 men and a foreman 37 working days to clean the sand in a half-acre filter bed, containing 1800 cu yd of sand. With the equipment described above, the rate of picking up the sand, washing it and replacing it is 9 cu yd per hr. This should complete the task in 25 days but, because it is necessary to install and remove equipment, to move sand to one side to make working room, and to clear out clogged ejectors, 12 additional days are required.

Although slow, the process is effective. It prepares the sand so that an annual wash with the mechanical washer, plus 5 harrowings, keeps it in good condition for 7 years. To take a more precise measure of its effectiveness, recourse is made to tests which show the permeability of the sand. A vertical core of the top 12 in. of sand is taken from a filter bed in a permeameter and the coëfficient of permeability, as employed in the Darcy formula for seepage of water through soils, is measured. This formula reads that the quantity of water that will flow through soil is a product of the coëfficient, the cross-sectional area, the slope of the hydraulic gradient and the time. That is,

$Q = k\ A\ S\ T$, where
k = Darcy coëfficient in ft per day,
A = cross-sectional area of the soil in sq ft,
S = head in feet per foot of length of the path through the soil,
T = time in days, and
Q = quantity (cu ft) of water that will flow through the soil.

Typical coëfficients obtained from tests made on a filter that was re-conditioned last winter were as follows:

dirty sand before it was re-conditioned = 15 ft per day;
clean sand after it was re-conditioned = 65 ft per day.

The tests were made with tap water at a temperature of 70°F.

In other words, the sand in this bed could filter water more than 4 times as fast after re-conditioning as it could before, provided there were no limitations in the hydraulics of the underdrainage system.

The effluents of all filters discharge into one or the other of two concrete storage basins, whose combined capacity is 15 mil gal. Because filters are operated at uniform rates, 7 mil gal of this storage are utilized to absorb the fluctuations in demand and the other 8 mil gal are always kept as an emergency reserve.

Two, 42-inch, cast-iron supply mains carry the water from the storage basins to the distribution system. Several hundred feet downstream from the basins, chlorine is applied to each of the mains by means of two, Wallace & Tiernan, automatic solution-feed chlorinators. The average dose for 1947 was 5.6 lb per mil gal, to maintain a combined residual of 0.20 ppm. Either chlorinator is of sufficient capacity to provide this residual in both mains under normal conditions. Two

sources of electric power are available to operate the chlorinator pumps and, in addition, there is on hand a pump driven by a gasoline engine, to take care of the eventuality that the power line might be down.

The cost of operating and maintaining this filter plant in 1947, including chlorination, amounted to $7.00 per mil gal. For their money the consumers received water that had an average color of 8 ppm, a turbidity of 0.4 ppm and a total bacteria count at 20° C. of 1 per ml, and was free of taste and odor, and well within the standards of the U. S. Public Health Service.

THE NEW CLINTON, MAINE, WATER SYSTEM AND SOME OBSERVATIONS ON GROUND WATER

BY GEORGE W. COFFIN*

[*Read May 20, 1948.*]

The Clinton Water District

A mere description of the new Clinton water system would take only a few minutes and of itself would not be very interesting. More important are the reasons that led the town of Clinton to establish a water district and to authorize the construction of a modern water system, despite present-day high costs—as well as the means by which the source of supply was located. It is these phases that the writer proposes to discuss.

The town of Clinton is located about ten miles northeast of Waterville on the Sebasticook River, one of the principal tributaries of the Kennebec. Pine Tree Trail, one of the main highways through the State of Maine, passes through the village. The main line of the Maine Central Railroad from Boston to Bangor also runs through the town.

Clinton is typical of the smaller high-class Maine towns. It is a very desirable residential community, close to the thriving city of Waterville, and supports three industries, a sheepskin-tanning factory, a woolen mill and a canning factory. Farming is carried on outside the village limits.

With all its advantages, however, the town lacked the two essential utilities for modern living standards—a water supply and a sewerage system. Water was obtained from household wells. Sewage was cared for by cesspools and septic tanks, in many cases in close proximity to the wells. The water was hard, of unsatisfactory quality and of uncertain yield in dry times. For fire protection chief reliance was placed on the waters of the Sebasticook River, with wells and cisterns for use where distances were too great to obtain water from the river. It might be appropriate to add here that, although the presence of a

*Consulting Engineer, 68 Devonshire St., Boston 9, Mass.

large river close to a town appears to provide ample water for fire protection for use with fire pumpers, it is not the *quantity* in itself that counts but how quickly the available water supply can be brought to bear on the fire.

To eliminate the sanitary and fire hazards, the town petitioned the legislature in 1945 for a charter[1] for a water district, to include the built-up section of the town. The charter was accepted by the voters of the town and the writer was subsequently retained by the Water District as Engineer to design complete water and sewerage systems for the District.

A fire which completely destroyed the garage and filling station of one of the Trustees of the District, together with a fire which leveled a wooden-frame dwelling in the heart of the business district, undoubtedly influenced the inhabitants of the District to vote for the proposed water system, despite the high estimated cost.

The town has a population of 1,500, of which about 800 persons reside within the limits of the District. For design purposes an average of 60 gal per day per capita was assumed, equivalent to an average daily consumption of about 50,000 gal. Industrial requirements were estimated to be about 58,000 gal per day during the 10 or 12 weeks of the canning season. Both the tannery and the woolen mill propose to continue to use brook and river water for process water. Fire flows were based on a rate of 1,500 gal per min for a 4-hour fire, in addition to domestic requirements.

Location of Source of Supply

A large river flowing through a town, especially if the water appears to the eye to be reasonably clean, is an attractive source of supply. In this case, however, the Sebasticook River was briefly considered but was rejected, as it carries the domestic sewage from several large towns upstream, woolen-mill and canning-factory wastes and other forms of pollution.

A small brook with a drainage area of about 15 sq mi flows through the town from the north. There is no storage on this brook and there are no practicable sites for a dam. It was unlikely that the dry-weather flow of this stream would be sufficient for the needs of the District and this source was not considered further.

[1]Chapter 72 of the Private and Special Acts of Maine, 1945.

A ground-water supply, accordingly, appeared to be the only practicable solution. Numerous surface gravel deposits in several small valleys throughout the District indicated that, if gravel could be found deep enough below the ground-water level, a suitable gravel-packed well could be obtained.

Test Wells

In locating a source of supply for a small community, it must be borne in mind that the source must be located as near the distribution system as practicable, in order to avoid long, non-productive supply mains. For rough estimating, such a supply main may be assumed to cost $35,000 to $50,000 per mile. We were, therefore, limited to an area within a radius of about 1 1/2 miles from the center of the District in which to look for a supply.

Eight 8-inch test wells were driven in this area and, although surface gravel deposits and topography indicated that the gravel might be expected to extend into the ground water, such was not the case. The test wells were all driven to bed rock and varied in depth from 16 ft to 45 ft. Clay, hardpan and fine sand were found but no water-bearing gravel. At this point the available appropriation for well testing was nearly spent and the situation was discouraging. However, the Trustees were prevailed upon to try at least one more place—and that was it. An excellent water-bearing gravel was found in a gravel pit and within 1/2 mile of the center of the District. The writer would like to point out here that money spent for well testing is not wasted, but is just as important a part of the investigation as the design and specifications for the rest of the system. Money judiciously spent for well testing is money well invested.

An 8-inch test well with an 8-inch-by-10-foot screen was driven to rock in this pit. Bed rock was found 38 ft from the surface. Static water level was only about a foot below the surface. A pumping test indicated that a yield of at least 300 gal per min could be obtained, which was more than ample for the needs of the District, and it was decided to acquire this site for a permanent gravel-packed well. Eight acres were subsequently purchased.

Analyses by the Maine Department of Health showed the water to be of excellent quality, except that the hardness of 84 ppm was

greater than the residents considered desirable. The final pumping test, after the gravel-packed well was installed, was conducted over a period of 51 hr at the rate of 500 gal per min and showed a drawdown of only 12 ft. Recovery nearly to static water level occurred within a few minutes after stopping the pump and complete recovery within a few hours. Although this test indicated far more than enough to supply the needs of the District, it was not deemed advisable to install a pump of greater capacity than 300 gal per min—the original estimate of the safe yield of the well. Pumping at this rate will supply the normal demands of the District with only a few hours' pumping. For the high flows required for fire service a 400,000-gal standpipe was designed and located on a hill just east of the town, so as to give the required flows by gravity.

Cost of Test Wells

The 9 test wells, including an 8-inch-by-10-foot test screen on the final test well and the pumping tests, cost $1,243.

Description of the System

The following is a brief description of the principal features of the system as designed and constructed:

Well

Type—stabilized gravel-packed
Depth—43 ft
Diameter outer casing—18 in.
Diameter inner casing—12 in.
Length of 12-inch Everdur screen—10 ft
Final pumping test—51 hr, continuous
Yield during test—500 gal per min
Installed pump capacity—300 gal per min
Drawdown for normal use—6 ft
Yield per foot drawdown—50 gal per ft

Pumping Equipment

Type of pump—Deep-well turbine—water-lubricated
Make of pump—Pomona—automatic operation by a pressure-controlled switch
Size—8 in.
No. of stages—10
Rated capacity—300 gal per min against 195 ft total dynamic head
Prime mover—G.E., vertical, hollow-shaft electric motor, 20 hp, 220 volts, 3-phase, 60-cycle, A.C., 1750 rpm
Standby power—Continental, 4-cylinder gasoline engine, rated at 30 hp at 1750 rpm, direct-connected through flexible shaft and Fairbanks-Morse right-angle gear-drive having 1:1 ratio

Auxiliary Equipment

Flow meter—Builders-Providence, orifice type, 10" × 4" differential, with "Flo-Watch" electrically driven, indicating, integrating, totalizing, recording instrument, having 24-hour record charts

Chlorinator (for emergency use)—Wallace and Tiernan, solution-feed hypochlorinator, having a capacity of 5 lb of 1% solution per day

Pumping Station

Size—23' × 17' × 10'—8" average clear height
Foundation—Concrete walls on concrete spread footings
Floor—Reinforced-concrete slab
Superstructure walls—Brick masonry
Superstructure roof—20-year tar and gravel on wood-joist and plank deck
Standby engine room—Separated from pump room by brick wall
Pump room—Houses the pump, electric motor, softening equipment, meter, gauges, heater and all controls
Heater—Automatic, forced-hot-air type, fired by gun-type oil burner

Water Softener

Make—Infilco
Type—Zeolite pressure type, with sodium-chloride regeneration
Capacity—Reduces from approximately 104 ppm hardness to 20 ppm—about 35,000 gal between regenerations
Controls—Selective—either fully automatic or manual through entire cycle of soften, backwash, regenerate, rinse and back to soften

Standpipe

Capacity—407,000 gal to overflow
Type—A.W.W.A., all-welded, flat-bottom steel reservoir
Diameter—46' 0"
Height—32' 6" from base to overflow
Auxiliary equipment—12"-diam. fill-and-draw conn.
6"-diam. blow-off conn.
8"-diam. overflow
Steel-plate roof with hinged roof hatch
Access and inspection manhole in first ring of tank
No ladder

Distribution System

Pipe—Centrifugally cast, cast-iron B & S, class 150—U. S. Pipe & Foundry Co.:
6"—6,403.5 lin ft
8"—7,501.1 lin ft
10"—4,568.1 lin ft
12"—3,222.1 lin ft
Total footage 21,695 lin ft, of which 2,118 lin ft are stock-piled for future extensions. 5-foot minimum cover

Valves—A.W.W.A. standard valves at all pipe intersections and line valves, approximately 1000 ft apart—R. D. Wood Co.

Hydrants—35 A.W.W.A. standard, 5" × 5½' bury, on 6"-diameter branch connections—R. D. Wood Co. Each hydrant has 6" auxiliary gate valve. Hydrants have two 2½" hose connections and one 4½" pumper connection

Pressures—Pressures are fairly uniform throughout the system and average about 53 lb per sq in. in the center of town

Flows—Fire flows are ample for all ordinary fires and a flow of more than 2,000 gal per min can be obtained in the business district, near the Town Hall

Construction Cost

The construction costs of the water system and of the sewers were as follows:

Water System	
Well and pumping equipment	$ 9,500
Pumping station	3,300
Standpipe	14,000
Distribution system	136,000
Softener	6,900
Total Cost of Water System	$169,700
Cost of Sewers	57,800
Grand Total Construction Cost, Not Including Engineering, Legal Fees, or Real Estate	$227,500

Some Observations on Ground Waters

It is not the purpose of this paper to go into a discussion of the hydraulics of wells or the geology of ground water, but rather to point out some simple observations that may be of assistance to superintendents who may be planning new or additional ground-water supplies. If some of my remarks seem elementary, it is because it has been my observation that often simple facts are overlooked and a problem is made to appear more complicated than it really is.

All ground water as well as surface water comes from precipitation from the skies. Some of this precipitation runs off over the surface of the ground into the streams, ponds and lakes. Some of it is absorbed by growing vegetation; some of it evaporates, and the rest of it percolates into the ground, to form a reservoir of so-called ground water. This ground water is in constant movement toward lower levels, where some of it emerges in the river valleys and maintains the so-called dry-weather stream flow. The distance from the surface to this ground-water reservoir varies with the topography and is generally greatest near the top of a hill, and least in the valley floors. Often in prospecting for ground water I have had springs pointed out to me on hillsides, or even very close to the top of a hill, as being possible sources of supply, on account of their apparently continuous flow. But little water can be obtained from such sources. The reason why such springs exist is that at some distance below the surface there is an impervious stratum, which prevents the ground water from pene-

trating deeper, and, with the pressure from above, this water is forced to the surface, to form the springs and upland swamps. My homely analogy to illustrate the futility of attempting to obtain any appreciable quantity of ground water from a hilltop or high up on a hillside is to point out that you can get more cider out of a barrel by putting the spigot in the bottom than at the top.

It does not necessarily follow, however, that a ground water can always be obtained from a valley. The bedrock in many of our New England valleys lies very close to the surface and it is only in those deep pre-glacial valleys which have been filled with sand and gravel in some past age that any large quantity of water can be obtained.

Although clay may be saturated with water, it is not practicable to obtain a ground-water supply from a clay formation, due to the extremely slow rate at which water can be drawn from the clay. Our New England granites and rocks are generally too dense to yield more than limited quantities of water and, although a rock-drilled well may supply an individual dwelling, the yield of such wells is far too limited to be considered as a source of supply for any but the smallest municipalities.

The problem then becomes one of locating a sand-and-gravel deposit of sufficient depth below the ground water in which to install a well and of determining the extent of this water-bearing deposit. Water must be found where water is and, despite the claims of the well dousers, and although electrical prospecting methods have their place in geological exploration, the only practicable method of locating a ground-water supply is to dig a well and find out. Merely to determine the existence of ground water is not sufficient. The extent of the water-bearing material and its depth determine the yield of the well and whether a given well will furnish sufficient water year-in and year-out, at times of drought as well as during periods of normal rainfall. It is a well-known fact that in periods of drought, when the ground-water level is at its lowest, the water consumption is generally at its peak. The chemical and bacteriological character of the water is equally important and the yield and quality of the water can only be determined by an adequate pumping test from properly installed test wells.

For a preliminary reconnaissance, 2 1/2-inch test wells with open

ends or well points may be used and are practicable in soils where hardpan and boulders are not expected to be encountered. An area having been located by preliminary reconnaissance where indications are that sufficient water can be obtained, 6-inch or 8-inch test wells, driven to sufficient depth to penetrate the lowest water-bearing strata, should be installed. A strainer of proper size for the size of material encountered should be used with this test well, in order that a pumping rate at least equal to the maximum expected demand from the well can be maintained. Also, by using 8-inch test wells, a better knowledge can be obtained of the material penetrated by the well than by means of 2 1/2-inch wells together with wash-boring methods of determining the underlying strata.

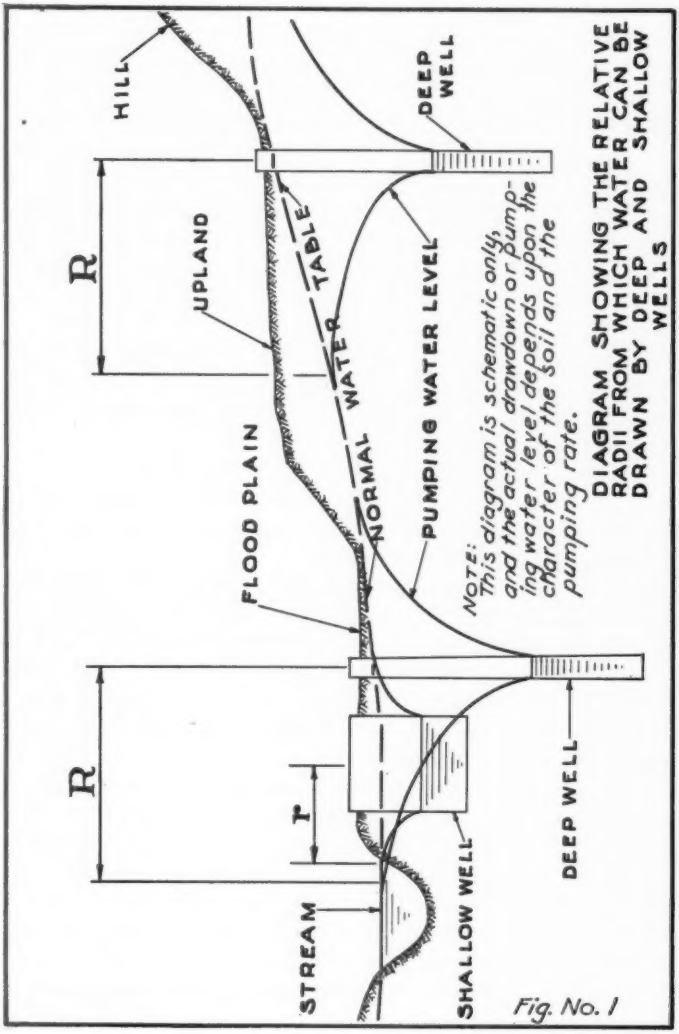
After installing the 8-inch test well and before beginning the pumping test, it is well to install sufficient 2-inch or 3-inch observation wells, at distances of 50 to 1,000 ft or more from the main well, to determine from what area water is drawn.

The duration of the pumping test is also important, as with a sufficiently long test the yield can be accurately determined. Also, any changes in the character of the water, as well as the effect of distant pollution, can be detected.

The source of supply is the most important part of a water system and the cost of a well supply is usually but a small part of the entire cost of the system. Too much emphasis cannot be placed on the importance of thorough testing by means of test wells, to insure that the proposed new source, or additional source of supply, is adequate. It is false economy to try to save money on this important phase of the engineering for a new supply.

It is easy to provide additional standpipe or reservoir storage, or pump capacity, as the system grows, but to attempt to increase the yield of a well of insufficient capacity is a difficult problem.

Figure 1 is a schematic diagram showing the comparative distances from which water can be drawn for shallow and deep wells. Wells are frequently located in a flood plain, in close proximity to a river, with the idea that the intervening sand and gravel between the well and the river act as a natural filter. If the adjacent stream is polluted, gradual deterioration of such wells is almost certain to occur. In locating a well in a river valley, it is well to locate it above


HILL
R
UPLAND
DEEP WELL
NORMAL WATER TABLE
FLOOD PLAIN
PUMPING WATER LEVEL
NOTE:
This diagram is schematic only, and the actual drawdown or pumping water level depends upon the character of the soil and of the pumping rate.
DIAGRAM SHOWING THE RELATIVE RADII FROM WHICH WATER CAN BE DRAWN BY DEEP AND SHALLOW WELLS
R
r
STREAM
SHALLOW WELL
DEEP WELL
Fig. No. 1

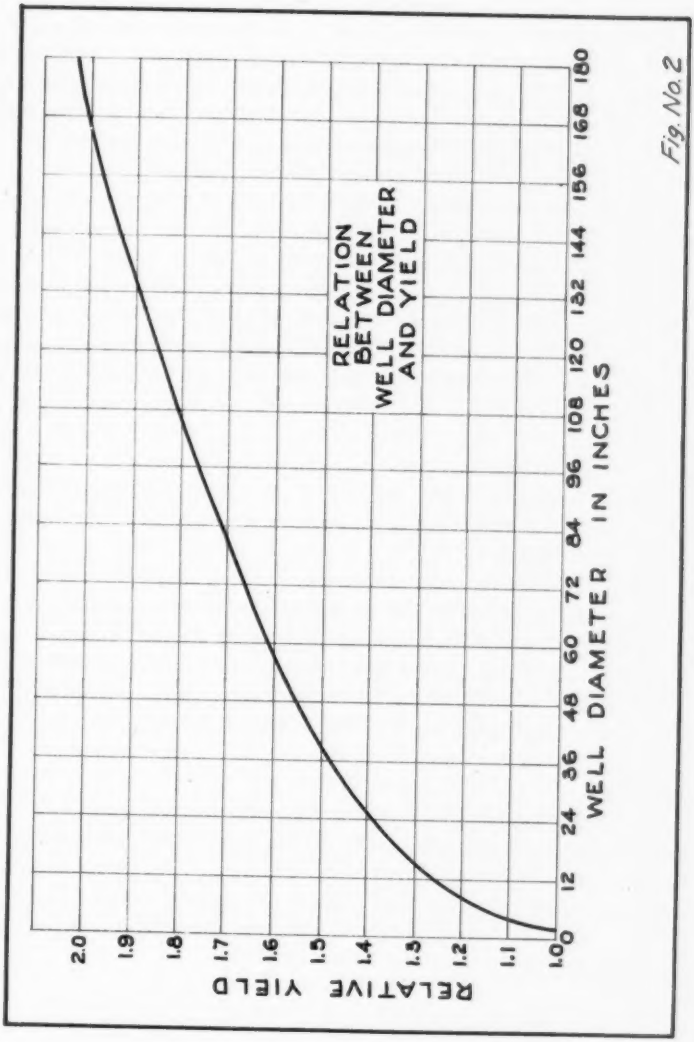

RELATIVE YIELD
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.00
0 12 24 36 48 60 72 84 96 108 120 132 144 156 168 180
WELL DIAMETER IN INCHES
RELATION BETWEEN WELL DIAMETER AND YIELD

Fig. No. 2

the flood plain and at sufficient distance from a stream so as not to draw river water into the well. Figure 1 is drawn on the assumption that the water-bearing gravel is uniform. In some cases, it is found that there is a tight layer of material above the water-bearing gravel, which tends to seal off surface water, and that the water in the lower levels has quite a different character from that in the upper levels.

A large-diameter well, in which a considerable volume of water can be seen, appears to many to be a more certain source of supply than a small-diameter well of, say, 12 or 18 in. It is the depth of the well rather than the diameter that is important, as with a deep well usually a greater yield can be obtained, by being able to draw from greater distances than with the shallow well. Figure 2 shows the approximate relation between well diameter and yield. The actual shape of such a curve depends upon the physical characteristics of the water-bearing soil.

Gravel-Packed Wells

Having located a source of supply by means of test wells, the writer would now like to say a few words about the methods of obtaining this supply.

The earliest method of obtaining a ground-water supply was simply digging a well into the water-bearing substrata. This is still a good method under some conditions, provided the well is constructed to prevent the entrance of surface drainage and local pollution.

Later, pipe wells came to be extensively used. Such wells were generally not more than 40 to 60 ft deep and the required supply was obtained by connecting a large number of these wells to a common suction header.

With the advent of improved drilling methods and a better understanding of the hydraulics of ground water, the so-called gravel-packed well has been developed. There is nothing magic about a gravel-packed well nor is such a well always the answer to ground-water problems. It should be kept in mind that, before deciding on a gravel-packed well, suitable tests are still necessary, as previously pointed out.

Basically, a gravel-packed well is simply a pipe well of large diameter—usually from 8 to 24 in. or more in diameter—with a screen

set at the lower end of the pipe. By using a heavy well-drilling rig or by caisson methods, such wells are usually set much deeper than the ordinary, shallow dug well or small-diameter pipe wells. By constructing a gravel-packed well to a depth of 50 to 100 ft or more, depending upon the character of the substrata, the effective diameter of such a well is greatly increased, because it is possible to draw the water level in this well down much more than with a shallow well.

The writer does not intend to go into the details of construction of a gravel-packed well but simply to point out the advantage of such a well where tests indicate that a well of this type is practicable. The so-called "gravel pack" permits the use of larger openings in the screen than would otherwise be possible. The gravel pack also serves to prevent the entrance of fine sand through the screen into the well, by keeping the velocity of the water entering the well at a minimum. In many locations it is not necessary to add a gravel pack around the screen, if tests of the material penetrated in driving the test wells show this material to be of suitable size to use without the addition of gravel around the screen. In other words, it is often possible to construct what is known as a natural gravel-packed well, by simply driving the well into the substrata and, after pumping out the fines, the well is ready for use. It should be borne in mind in locating a gravel-packed well that the effective diameter, or distance from which water is drawn into a well, is generally much greater than for a shallow well and care should be taken in locating this well so as to have it beyond the reach of any surface pollution, such as that from fertilized farm lands, sewage-treatment works, etc.

Acknowledgments

The Clinton Water District is operated by a board of three Trustees—Frank A. Besse, Chairman, Vinal Galusha and Neal A. Phelps. Clarence Robinson is Town Manager and Superintendent of the Water District. The water and sewerage systems were constructed under six contracts as follows:

1. Well and pumping equipment—The R. E. Chapman Co., Oakdale, Mass. The Aetna Engineering Co. of Boston was sub-contractor on the pumping equipment.

2. Pumping station building—Louis N. Violette, Waterville, Me.
3. Standpipe—Chicago Bridge & Iron Co.
4. Distribution system—C. Reppucci & Sons, Inc., Boston, Mass.
5. Water softener—J. F. McGlame Co., Brookline, Mass. The International Filter Co. (Infilco) furnished the softener.
6. Sewerage system—C. D'Alfonso Co., Portland, Me.

The system is now completed and the works are in operation. Full credit is due to the several contractors and manufacturers who furnished materials and equipment for their coöperation in bringing the work to a successful conclusion, and the writer takes this opportunity to extend his thanks to them.

PROCEEDINGS

April 1948 Meeting

Farmington Country Club, Farmington, Conn.

Wednesday, April 21, 1948

President Donald C. Calderwood in the Chair.

The Association was welcomed by Charles R. Goodwin, Chairman of the Hartford Metropolitan District Commission.

Introduction of Caleb Mills Saville, Consultant to the Hartford Metropolitan District Commission and Honorary Member of the Association, was made by Mr. Goodwin. Mr. Saville gave a brief resumé of the Saville Dam.

A paper "Methods of Cutting Cast-Iron Pipe" was read by Sherman L. Rogers, Superintendent of Distribution, Water Bureau of the Hartford Metropolitan District Commission.

A paper "Operation of the Slow-Sand Filter Plant of the Metropolitan District, Hartford, Connecticut" was read by Alexander J. Minkus, Senior Assistant Engineer, Water Bureau of the Hartford Metropolitan District Commission.

A paper "The Saville Dam and Barkhamsted Reservoir" was read by William Dorenbaum, Chief Designing Engineer, Water Bureau of the Hartford Metropolitan District Commission.

A motion picture, in color, of the Hartford Water Supply was then shown.

MAY 1948 MEETING

MUNICIPAL AUDITORIUM, DOVER, N. H.

Thursday, May 20, 1948

President Donald C. Calderwood in the Chair.

The Honorable Simon Markos, Mayor of Dover, extended his greetings to the members of the Association.

A paper "Council-Manager Form of City Government" was read by Woodbury Brackett, City Manager, Dover, N. H.

A paper "The New Clinton, Maine, Water System and Some Observations on Ground Water" was read by George W. Coffin, Consulting Engineer, Boston, Mass.

A paper "A Study of Sludge Disposal at Water Purification Plants in New England" was read by Fred E. Smith, Chemist, Water Department, Cambridge, Mass.

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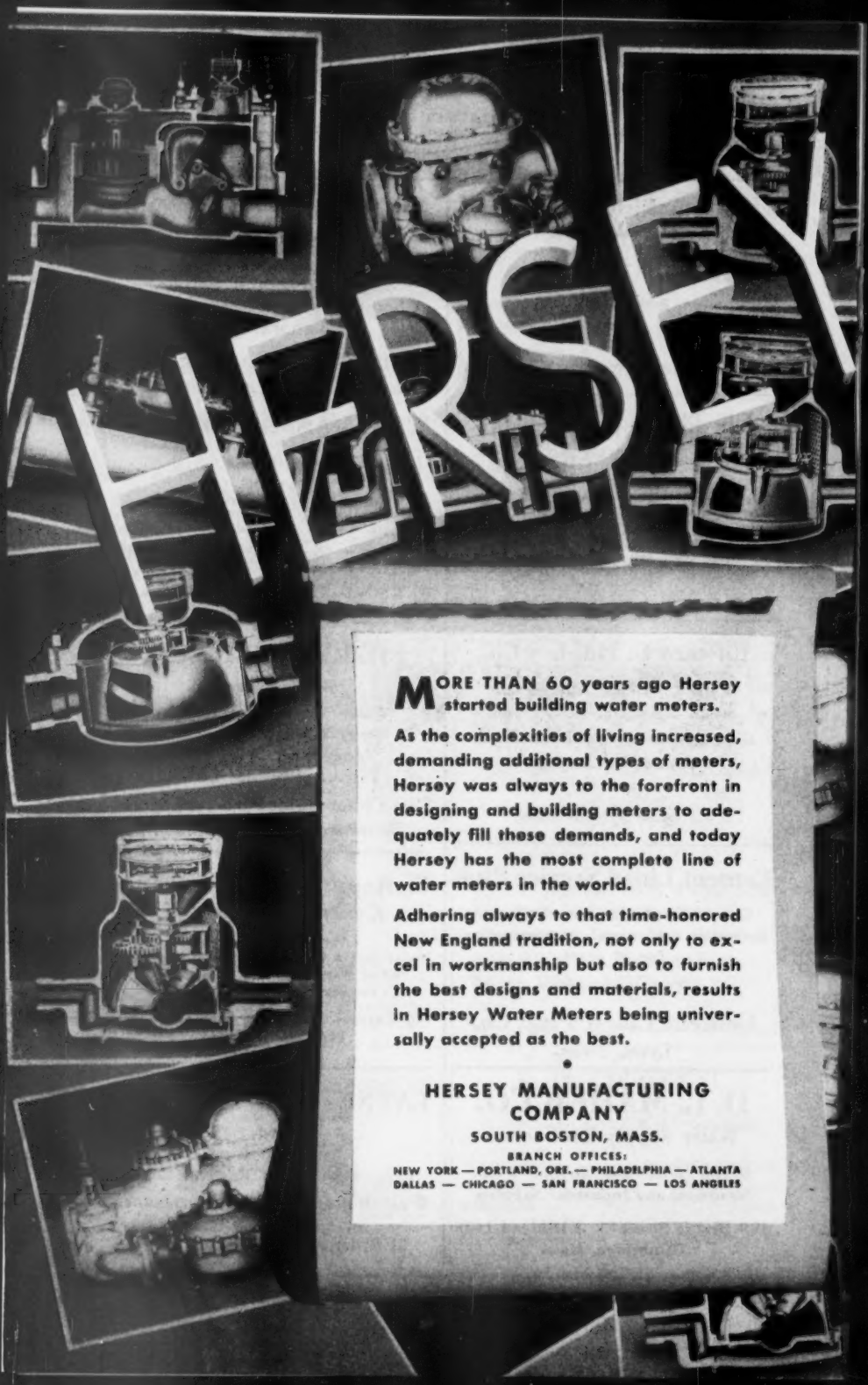

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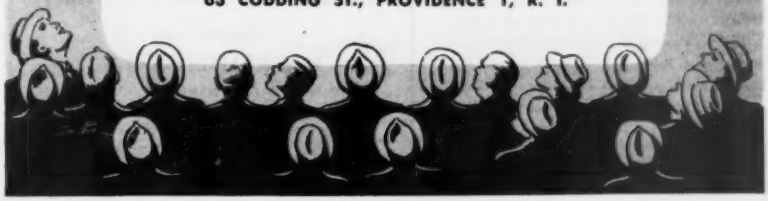

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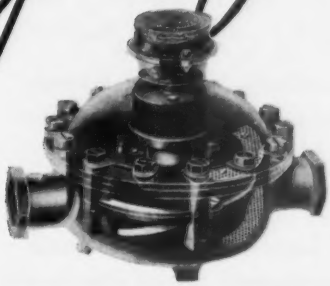

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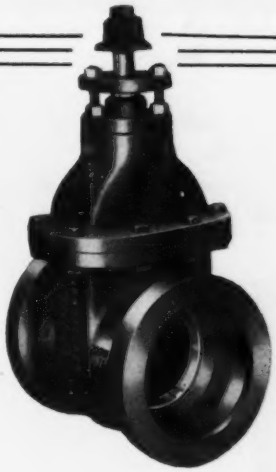

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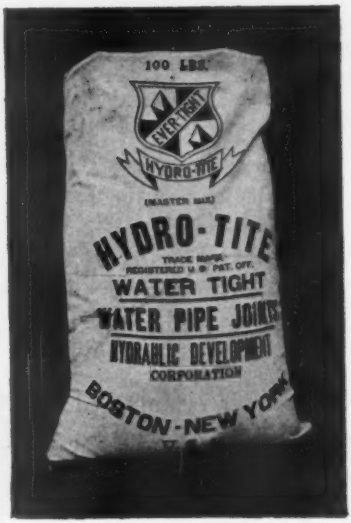

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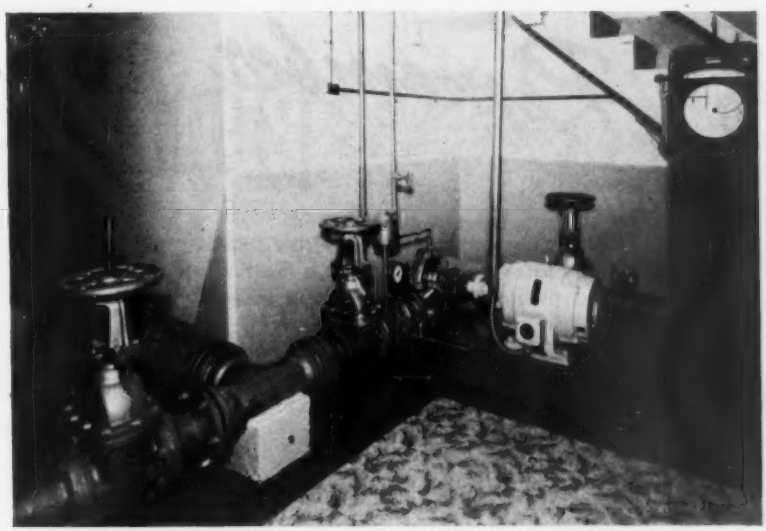

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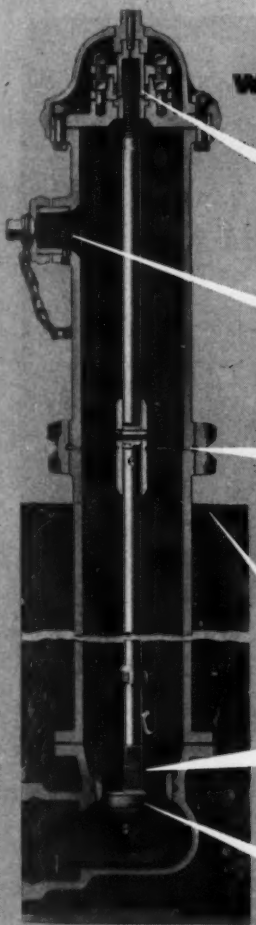

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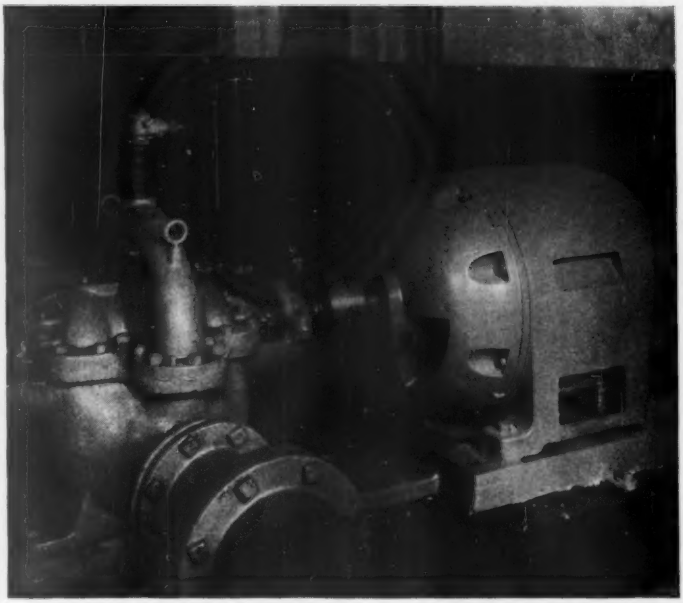

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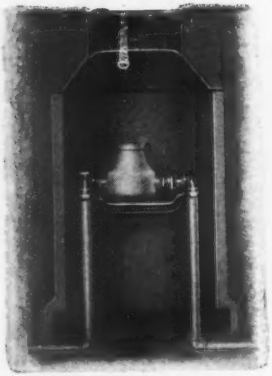

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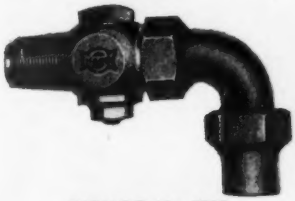

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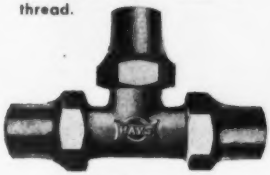

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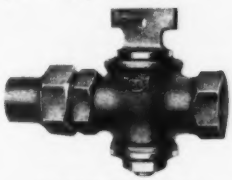

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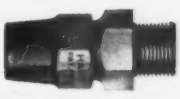

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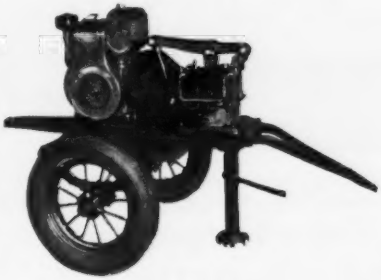

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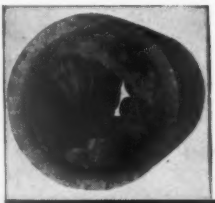

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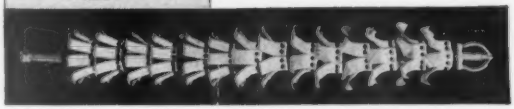

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Controls elevation of water in tanks, basins and reservoirs

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1. Single Acting
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Maintains desired discharge pressure regardless of change in rate of flow

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Regulates pressures in gravity and pump systems; between reservoirs and zones of different pressures, etc.

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Electric remote control—solenoid or motor can be furnished

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Manufacturers of

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Immediate delivery can be made to waterworks on both wrought iron and steel, black or galvanized.
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96%

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FOR WATER, GAS, SEWERAGE
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